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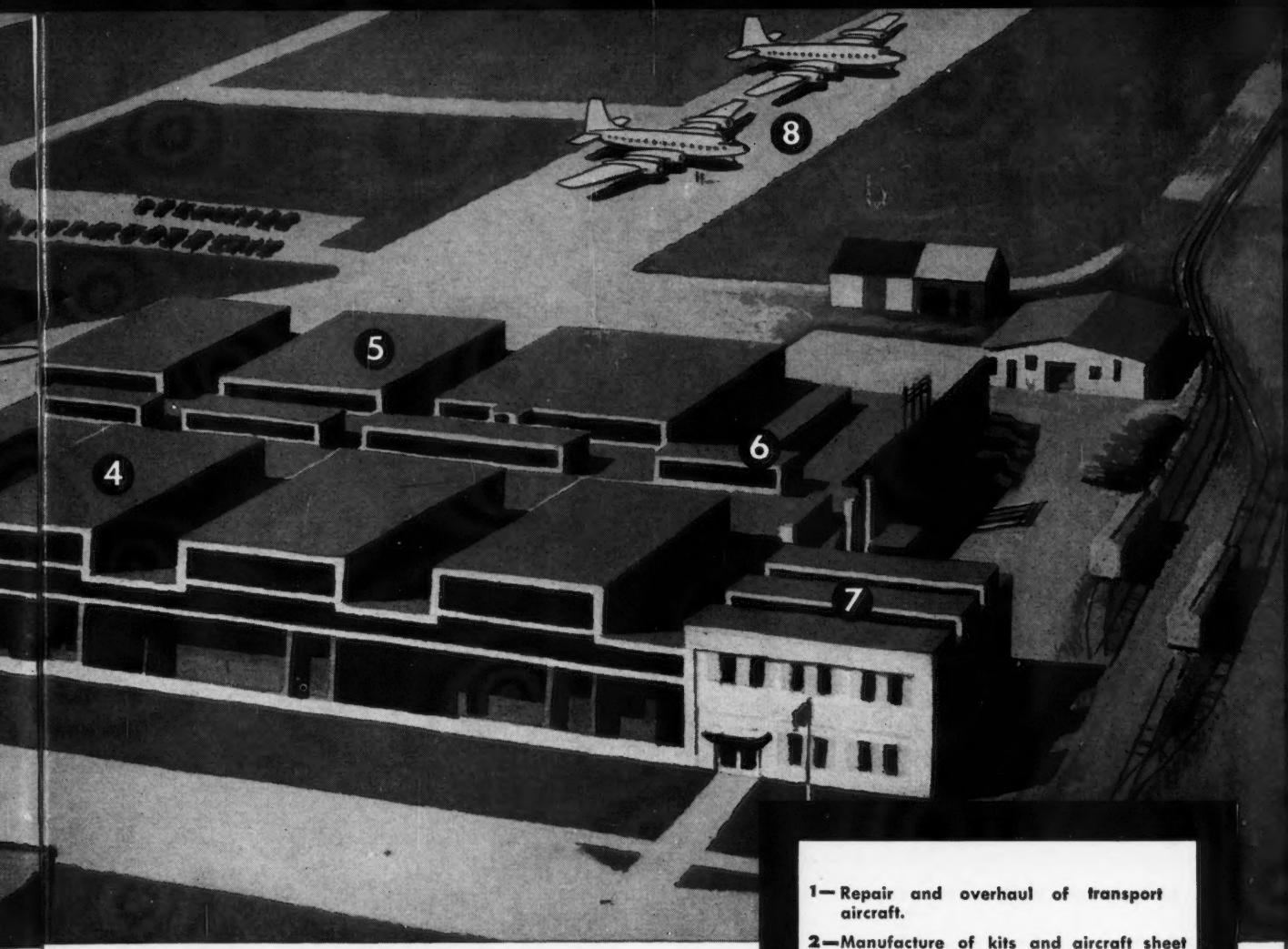

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MONTREAL 18

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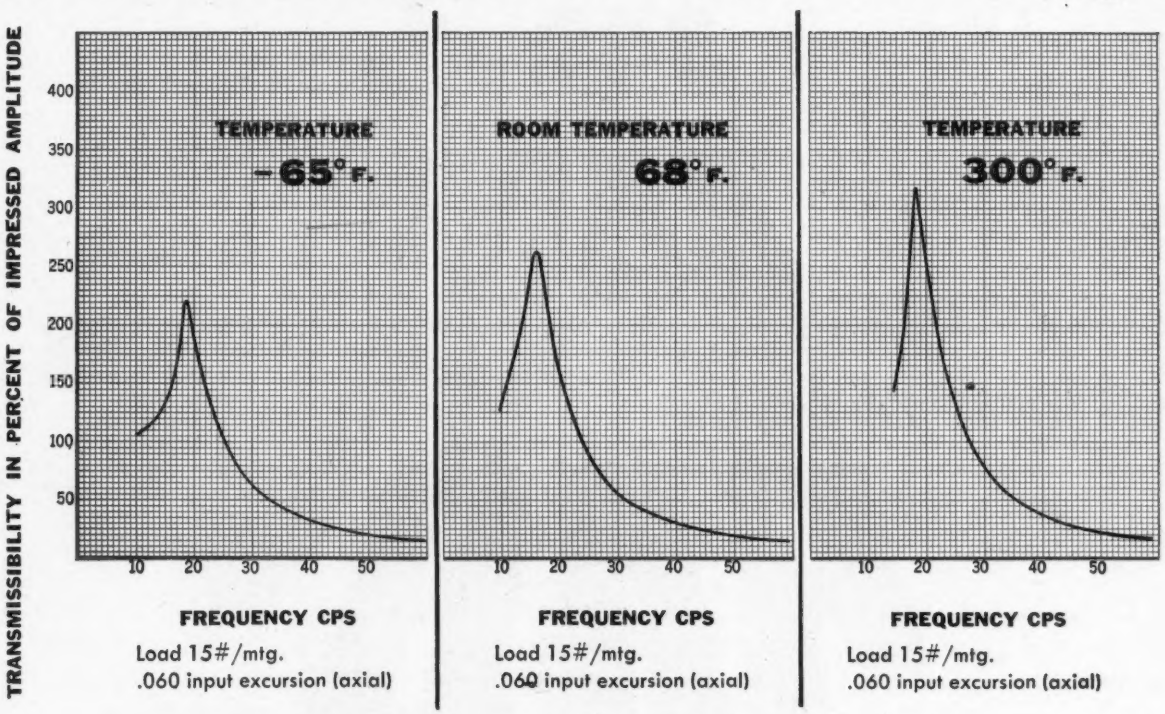

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EDITORIAL

CAN WE ELIMINATE THE SHORTAGE OF PROFESSIONAL MANPOWER?

For the past six months, the Canadian public has been subjected to a barrage of words from journalists, commentators and men in public life on the inadequacy of our scientific programme and our educational system. The launching of the first Sputnik threw the western world into a frenzy of competition – competition for scientific and technological achievement, international prestige and power. The launching of Sputnik, if it has done nothing else, has at least made more people aware of the necessity for taking stock of our resources and for making plans to fill in the gaps. The largest gap has been said to be the lack of professional manpower, especially in the areas of science, engineering and teaching. This gap had, however, been noticeably large, even before Sputnik I sailed onto the horizon before our astonished eyes. In 1956, at the Conference on Scientific, Engineering and Technical Manpower held at St. Andrews, the conclusion was reached that if Canada were to graduate a sufficient number of engineers and scientific personnel to look after the needs of our growing economy, and to maintain some sort of equality with the U.S.A. and the U.S.S.R., we should have to increase our university population by the year 1980 until it reached 375,000 or even 490,000. When it is considered that our present university student population is around 75,000, the seriousness of our position seems insurmountable. What are the prospects?

The statisticians tell us that, simply by reasons of natural increase of population, the number of college-age young men and women will increase enormously during the next ten years, from 900,000 (of whom about 7% attend university) to 1,228,000 in 1965. As well, the proportion of these who go to university is likely to rise and, as our society becomes more complex and technological, the cry for the expert, who is usually a university graduate, becomes increasingly clamorous. And so, by 1965, we are certain to have double the present number of students, or about 150,000, in our universities. Perhaps more will be recruited through larger and more numerous bursaries and loans from governments.

The fact has been established that greater numbers of professional and technical people are needed; indications are that the raw material – the 18 to 21-year olds – will be available in double the present quantity. The big problem, then, is – where are these people to be trained? Can the universities accommodate this unprecedented number of students?

Two main areas are involved here – the university plant and the university staff. All across the country the universities are planning for the required expansion and resorting to new methods (for academics) of unapologetic fund raising. Society is depending on the universities for leaders, but the universities, in truth, must depend on society for the finances to produce them. Finances would completely solve the problem of the supply of bricks and mortar for physical expansion and would also do much to solve the problem of staffing the universities. Every university in Canada has long-range plans for expansion of its campus, and the realization of these plans is a simple matter of a continuous supply of funds for capital purposes. However, the staff problem is more complex. The best, the most inquiring minds, the scholars of the first order, are vital requirements in the university's business of expounding to the able what is known about the great areas of human knowledge and exploring with the able what is not known. There are approximately 6,000 university teachers in Canada today and by 1965 there should be, at the very least, about 10,000. Where are the extra 4,000 highly-qualified teachers to come from? A long period of post-graduate training is required for a scholar to qualify for a university position. In order that we may be able both to encourage young graduates to continue their training and to lure established professional men back to the university, the universities must be in a position to offer them adequate economic awards and social prestige.

The money required to make our universities strong is ludicrously small when put in the perspective of our total resources. Money so spent will return fantastic dividends – in trained professional manpower, in informed public opinion and in the development of our cultural life. It is unthinkable that Canada should not see this opportunity and grasp it quickly and firmly.

Dr. C. T. Bissell
President
Carleton University

BRISTOL COOLING FANS ON WRIGHT R2600 ENGINES IN RCAF MITCHELL

INTRODUCTION

Following investigation into the causes of 'in flight' fracture of R2600-13 and -29 cylinders at the head/barrel joint and the high incidence of oil leakage at the same location on engines installed in RCAF Mitchell aircraft, it was established that an overheating problem existed during ground operation, particularly under high ambient air temperatures. Under these conditions it was virtually impossible to keep cylinder head temperatures below the maximum limit during normal ground running, taxiing and pre-takeoff checks. On many occasions engines have had to be shut down to allow cylinder head and oil inlet temperatures to cool.

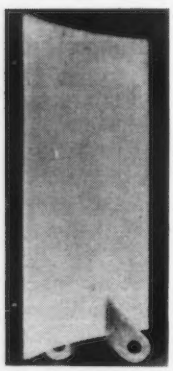

Figure 1 (left)

Figure 2 (right)

As a result it was considered most desirable to initiate some method whereby engines could be run cooler on the ground and thus reduce the tendency for cylinder head loosening and possible detonation.

Tests conducted on a Mitchell aircraft revealed that the airflow characteristics over the cylinders on the ground were extremely poor, due largely to the propeller blade root section being almost circular within the diameter of the nose cowling. With this in mind, Bristol Aero Engines Ltd. put forward a design to the RCAF for producing a simple fan, consisting of three separate blades which could be attached to the existing propeller hub bolts in between the propeller blades. By this means a greater airflow could be directed to both the cylinder barrel and the head, thus improving the dissipation of cylinder heat.

A trial set of blades was used for experimental purposes and the results during ground running tests on a Mitchell aircraft were so encouraging that further development of the fan was immediately put in hand. The finalized fan blade has been successfully tried out both on the ground and in flight under ambient ground air temperatures of up to 95°F. At these conditions no difficulty was experienced in running engines for as long as ¾ hr for compass swinging and at no time did cylinder head temperatures exceed 200°C. After normal pre-flight ground run, taxiing and takeoff checks, head temperatures only reached 150°C. Tests conducted on an installed engine, with thermocouples fitted to each cylinder, indicated that as much as 80°C reduction in head temperatures was achieved on hot running cylinders. The overall cooling effect produced was an average of 35°C.

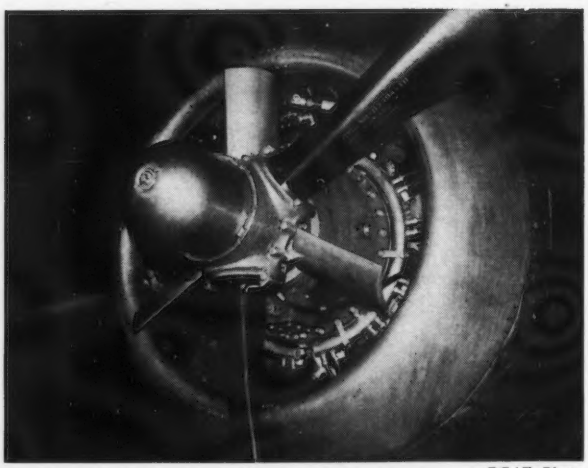

Figure 3 *RCAF Photo*

Blades have already been supplied to the RCAF and are being used on service aircraft.

Installing one set of three blades to the propeller hub requires no special equipment and can be accomplished by one man in no more than thirty minutes. Each fan blade is individually balanced statically and consequently no propeller balancing is required after fitting to the installed propeller.

DESCRIPTION OF FAN BLADE

The original set of blades was constructed from stainless steel but, in the interests of saving weight, a blade utilizing plastic material and still retaining adequate strength has been developed. The final configuration (Figure 1) consists of a "Urefoam" resin plastic (density 19 lb/cu ft) aerofoil section blade bonded to a stainless steel plate to which a bracket for attachment to the propeller hub bolts is welded (Figure 2). The plastic aerofoil section is fully encased in a polyester/fibre glass cloth jacket, the whole being produced by a moulding and oven baking process.

Each blade is 11⅜" in height from the centre line of the securing bolt holes to the top of the blade. The section of the blade is 10½" long by 6" wide, measured across the chord.

The blade core to which the blade is bonded consists of a 1/16" gauge perforated stainless steel plate welded to a 3/16" gauge bracket, the latter being accurately jig drilled to ensure correct fit to the propeller hub bolts. The weight of a complete blade is 1.53 lb, which is made up of 0.79 lb for the core and 0.74 lb for the blade.

A photograph of the installation on the R2600 engine is shown in Figure 3.

F. G. Philpotts
Bristol Aero Engines Limited
Montreal

SELECTION OF THE VICKERS VANGUARD BY TRANS-CANADA AIR LINES†

by J. T. Dyment*

Trans-Canada Air Lines

INTRODUCTION

Most airlines have a long range programme for their growth. The expression "long range" is relative to the industry. With the tremendous changes taking place in air transportation, the long range plans can generally only cover a ten year period but, in the case of TCA, they do cover plans for each year for the next ten years.

When the sales forecasting or operational obsolescence indicates it is time to order a new type of airplane rather than just more of the same, one does not merely visit a few manufacturers, fly in a few airplanes, and decide which one to buy. $100,000,000 may be at stake, so the decision could make or break any airline. As an added hazard, if the airline is to stay anywhere near the forefront of the industry, the decision will undoubtedly be between models of airplanes that are still in the drawing board stage of development.

Experience shows that the selection study should commence four to five years before delivery of the airplanes is required. The analysis itself can take two years and new types of airplanes can rarely ever be delivered within two years of being ordered.

The story of how the Vanguard was selected illustrates the work behind such decisions and exemplifies how these decisions are made today by any of the large carriers.

INITIAL ASSUMPTIONS

As a result of routine discussions of the forecast picture, top management may consider that five years hence will be the time to replace existing airplanes with a new type. Specialists from Operations Planning, Sales, Accounting, and Engineering, are then called in to agree upon common assumptions to use in the more detailed forecast studies.

These assumptions may cover the following:

(1) Expected economic level of the country and/or areas.
(2) Competitive factors.
(3) Routes and cities to be served.
(4) General type of equipment being considered.
(5) General class of service to be provided.
(6) General picture of rates to be charged.
(7) Total passenger traffic, mail and cargo expected.
(8) Maximum load factor desired.
(9) An acceptable approach to schedules.
(10) Likely interest rates for borrowed money.
(11) A review of the Company's objective in relation to its performance, profit etc.

The last item should always be reviewed to bring the Company's terms of reference afresh to the minds of those who will be making the study. This is not as simple as it looks because it is difficult to put into words the extent to which a company's objectives for safety, regularity, comfort, speed and economy, are compatible with each other and where one, for practical reasons, must give way to another.

It is generally agreed that the objective of any airline in peacetime is to provide a faster means of transportation than any other available. At the same time, it wishes to provide greater regularity and comfort than any other airline in order to keep its customers happy and to attract new customers. All airlines wish to achieve the ultimate in safety and do everything possible to help each other to attain it.

The cost of the airline's operation will depend to a considerable extent on the degree to which each is stressed. The maximum that can be plowed back into improvements will be limited by another objective common to the airlines, which is to provide an acceptable return to the stockholders for their investment, or to provide at least a sufficient margin of profit to keep the airline in the black considering unexpected operational costs that can occur in any airline's budget.

Another duty which must be covered, and one possibly more associated with a publicly-owned airline, is to provide services as inexpensive as possible to locations which would benefit the country as a whole, although not necessarily economically sound insofar as the airline itself is concerned.

The trick is to select airplanes that will provide a sufficient profit at the same time that the other factors are sufficiently acceptable to most of the people who use the airline.

SALES FORECASTING

Sales forecasting was mentioned. Most airlines maintain a continual study of traffic forecasts over the next few years. As we have said, TCA does so for a ten-year period on a point-to-point basis. TCA is not just interested in how many persons are carried between any

†Paper read at the Mid-season Meeting of the C.A.I. in Vancouver on the 27th February, 1958.
*Chief Engineer.

two adjacent points but it is very much concerned with the origin and destination of every traveller. The traveller usually prefers to fly non-stop directly to his destination. The airlines try to oblige as soon as the number of people wanting to do the same thing makes it economically possible. This point-to-point traffic analysis, over the whole system, is prepared by the Marketing Research Group of the Sales Department and provides a continual forecast of the following:

(a) Total number of persons from each point having the same destination.
(b) A breakdown of this total into traffic classes, such as first class, tourist etc.
(c) Minimum daily frequency of service desired between the two points.
(d) A maximum daily frequency that can be achieved without experiencing handicaps from traffic control (provided by the Operations Department).
(e) Times of departures desired by passengers.
(f) Amount of payload reserved for mail.
(g) Departure times desired by Post Office.
(h) Amount of payload reserved for cargo.
(i) Departure time desired by cargo shippers.
(j) A leg-by-leg analysis resulting from integrating all movements common to the various point-to-point demands.

For example, Vancouver people destined for Montreal would like to fly non-stop, but if there are not sufficient passengers to substantiate a non-stop flight, the flight could stop at Winnipeg and pick up Winnipeg passengers for Montreal. Therefore, the Winnipeg-Montreal leg of the analysis would show two figures; the total number of persons who could travel between the two cities regardless of their starting point or final destination, and the number of people who board at Winnipeg with Montreal as their final destination.

Aircraft types

On the basis of a first approximation of the above, the airline is generally able to decide how many different types and sizes of airplanes it needs or, to be more exact, how many different types it can afford.

Apropos of this, every different type of airplane requires an elaborate training programme of both flight and ground personnel to make them specialists on the new type. Each type of airplane requires further spare aircraft for maintenance, overhaul and operational protection. Each type of airplane requires additional spare engines, accessories, parts and materials. Each new type involves additional testing and ground service equipment. All of these cost money. The worst handicap any airline ever had in this respect was our compatriot, CPA, when it was first founded. I believe CPA originally owned over forty different types of airplanes and engines as a result of acquiring a large number of small airlines. I imagine the present CPA staff shudder to even think of passing through such a stage. Today we all feel badly if we have half a dozen types to look after.

At the same time, it would be a fortunate airline indeed that could do its job with only one type. It must be recognized that different types are required to best meet traffic demands over the variety of flight legs comprising most airlines. For instance, TCA has flight legs from 47 miles to 3,645 miles in length. The objective is, therefore, to at least limit the number of different types to an economically acceptable minimum.

In the case of TCA, although there are individual services, such as Vancouver-Victoria, that could use an airplane specifically designed for the purpose, the cost would be prohibitive. It is believed that three general types of airplanes will best suit the whole airline; a local intercity or short haul feeder airplane, such as the Viscount; a large intercontinental or long haul transcontinental airplane, such as the DC-8; and an intermediate type for major intercity or medium range services for which the Vanguard was selected.

Engineering data

Just as continual revisions are maintained of Sales' requirements, Engineering keeps a continual record of technical data, such as:

(a) airway mileages,
(b) runway lengths, gradients, permissible landings and approach clearances,
(c) airway and airport altitudes,
(d) airport and airway temperatures and humidities,
(e) en route and airport wind velocities and directions,
(f) seasonal percentile frequencies of various wind velocities and temperatures,
(g) hangar dimensions, and
(h) assumptions to be currently used by Engineering in relation to all new airplanes when studying their performance, weight and balance, route leg analysis and costing.

Manufacturers generally try to keep all of the larger airlines abreast with their development programmes so that at any moment the airline's Engineering Department can supply information about the general characteristics of the airplanes that are likely to be available during the next five or six years.

A broad picture of the airline's requirements can be established at any time, for any time over the next ten years, on the basis of the information mentioned. When it is time to move ahead and actually purchase a new type of airplane, the whole organization is thrown into gear to produce more detailed information.

PRELIMINARY SURVEY

The Engineering Department solicits information from all manufacturers that are likely to have something interesting, and thus commences the intensive study that may last two or three years. The objective is to first boil down the types being considered to a few of the more likely prospects and then compare the detailed designs of these airplanes, step by step, hoping to further reduce the number for final consideration.

In the case of the Vanguard, a number of airplanes were eliminated quite early in the study which finally led to a detailed comparison of two airplanes, the Lockheed Electra and the Vickers Vanguard. Just when this was completed, a number of newly proposed designs were offered by the manufacturers – the Douglas DC-9, the Convair Skylark, the Vickers Tri-Motor, the Bristol 420 Britannia, the de Havilland Comet 4 and, finally, the

Canadair CL44. The analysis was started afresh to cover the late entries.

To add to the task, almost as fast as a conclusion could be reached, one or another of the manufacturers would improve his design so the calculations would be started again.

In the Engineering analysis, one airplane was compared with another as well as against TCA's specific requirements.

The following items were covered in detail for ten contenders, while several late starters were examined separately to the point where they were dropped from further consideration as unsuitable:

Dimensions
Weight and balance
Aerodynamic characteristics
Engine data
Propeller data
Interior layouts
Performance
Structure
Powerplant
Instruments
Electrical
Radio
Hydraulics
Surface controls
Cockpit furnishings
Cargo facilities
Air conditioning
Pressurization
Anti-atmospheric
Water system
Oxygen system
Fire protection
Maintenance and servicing
Weights
Route study
Direct operating costs
Takeoff and landing characteristics
Range and speed capabilities

Standard of comparison

It might be of interest to mention that before direct operating costs and potential revenues could be calculated, it was necessary to establish a set of ground rules to apply to all aircraft in relation to their passenger accommodations. Originally one airplane would be laid out with the Queen Mary steamship type of thinking, while another would have seats jammed in like a commuters' train. One would have a galley capable of serving a convention, while another could not carry enough lunch boxes for a picnic. TCA worked with all the manufacturers in establishing a seating configuration for each that would be directly comparable from a quality standpoint and, hence, it would be fair to compare the resulting number of passengers that each could carry for the quantitative analysis.

Quantitative comparison

The charts that resulted from the analysis and assisted in deciding which is the most suitable aircraft from a quantitative standpoint are:

(1) Payload versus distance
(2) Block speed versus distance
(3) Direct operating cost per nautical mile versus distance
(4) Direct operating cost per available seat mile versus distance, for various seating configurations
(5) Break-even passenger load factor versus distance, for various fare levels
(6) Direct operating cost per available ton mile versus distance

Other characteristics were tabulated for the quantitative analysis, such as:

Takeoff distances for variations in altitude, temperature and payload range
Stalling speed
Approach speed
Landing distance
Runway requirements at all airports likely to be used
Cruise fuel consumption per hour
Holding fuel consumption per hour
Fuel reserves available
Fuel consumption penalties by operating away from ideal flight plan
Speed restrictions
Structural strength factors and permissible operating pressure differential for fuselage
One or two engine out climb and cruise performance
Component weights and tolerances demanded by manufacturers
Overall dimensions re existing hangar facilities
Volumes and area for passengers, baggage and cargo
Passenger seat dimensions, seat spacing and aisle width
Estimated cabin and ground noise levels

Route studies

Route studies were next performed comparing the prospective airplanes over each of the flight legs on which they will likely operate. The data, covering each season of the year, resulting from this study were tabulated as follows:

Point of origin
Origin altitude
Destination
Destination altitude
Distance, origin to destination
Alternate
Alternate altitude
Distance, destination to alternate airport
Cruise altitude
Cruise wind (50% used for costing)
Alternate wind (50% used for costing)
Block time
Block speed
Operational weight empty
Payload
Zero fuel weight
Alternate fuel
Landing weight
Route fuel
Takeoff weight

Takeoff runway length
Landing runway length
Number of passengers
Total passenger weight and baggage
Cargo and mail weights
Direct operating cost (DOC) per hour
DOC per nautical mile
DOC available seat mile
DOC less depreciation and insurance per hour
DOC less depreciation and insurance per nautical mile
DOC less depreciation and insurance per available seat mile
Break-even load factor for various fares (cents per seat mile)

Direct Operating Costs

In calculating costs it should be noted that it is impractical to use any simple ATA or SBAC formula to compare airplanes. Costs must be worked out for each route leg of the airline using as many actual costs as possible, such as fuel, crew salaries, landing fees, insurance, manufacturer's escalation, taxes and duty, guaranteed engine maintenance and overhaul material costs etc, plus assumptions based on the airline's own experience or plans, such as engine and airframe maintenance and overhaul labour cost, airframe maintenance and overhaul material costs, passenger service cost, depreciation period, estimated cost of modifications required to the standard production airplane to make it suitable for TCA services etc.

Direct Operating Costs only are considered in the comparative analysis as the allocation of indirect costs to various services within the airline would be most difficult to accomplish to everyone's agreement, but they should vary little by the substitution of one new airplane rather than another. It is assumed, therefore, that indirect costs will be the same for any of the new airplanes under consideration. The actual figure for indirect costs is only used when the total budget for the airline is being calculated.

One very important item in operating cost is the fuel cost and this is dependent upon the type of fuel selected. Two types, JP4 and Kerosene, were analyzed on the basis of where payload is limited by the landing weight, by the maximum gross weight and by the available takeoff runway length; and checks were made to ensure that there were no other limitations from an airplane standpoint. Initial cost, distribution costs, taxes, and the operating characteristics were considered for both types of fuel and as a result TCA has decided to continue to use JP4 in its turbines.

The Direct Operating Costs as determined by the Engineering Department are the estimated costs to operate each type of airplane over each particular flight leg.

Other considerations

On the basis of this information, plus a very comprehensive qualitative assessment of the detailed design of each airplane, its control characteristics, and all of its systems; plus a comparative opinion of the various airplane and engine manufacturers as to their ability to meet delivery dates and their weight and cost estimates, the maturity and efficiency of their Customer Service Departments, the experience of their design staffs with airline requirements, the past and likely future policy of the manufacturer as it would affect the airline and so forth; most prospective airplanes can be eliminated and the final phase of the study restricted to two or three airplanes.

As a result of the work to this point, it became evident that the designs most suitable for TCA's particular requirements were the Douglas DC-9 turbojet and the Vickers Vanguard turboprop.

OPERATION PLANNING

The Operations Planning Department in TCA carries the ball for the next phase of the study by applying the prospective airplanes and Engineering's calculations to the actual routes for which they would be best suited and integrating them with the existing TCA fleet.

For example, each of the intermediate size types also affects differently the number of smaller and larger airplanes required in the total fleet, both initially and as a continuing integrated programme. The most efficient fleet size of each type was determined in 1956 for two future periods, 1961 and 1966, to accommodate Sales' forecasts and obligations. This is a long detailed process and is based on first establishing a frequency pattern for the whole airline system.

Frequency Pattern

The development of the service Frequency Pattern for the airline on the basis of Sales' forecasts and technical information from Engineering is difficult to explain. The general approach is to be sure that long haul passengers are adequately looked after because all of the major airlines must depend on their long haul routes to support their short haul non-profit runs.

The size of the aircraft, the volume of traffic available and other factors are checked and eventually an economical route pattern is established using the larger of the prospective aircraft. Once this is established and if there are several contenders, the next largest aircraft is inserted into the picture and again, balancing volume with economics and service necessary, e.g. tourist and first class, a Frequency Pattern is developed for this type of aircraft. A review is then made of the minimum frequency requirements at stations, and the smallest aircraft is applied to bring these frequencies to at least minimum levels. In some cases, it may be necessary to back away from the use of a larger aircraft which provides us with one frequency per day and replace it with a smaller aircraft giving two frequencies per day. This whole exercise is a joint function between the Sales and Operations Departments, and eventually a Frequency Pattern for the period under consideration is developed which has taken into consideration non-stop operations, minimum frequencies, classes of service, carriage of commodities other than passengers etc.

Schedule

The Schedule is basically a timed Frequency Pattern. However, in developing the Schedule it may become necessary to make slight alterations due to location of maintenance bases, routing of aircraft, service to the community and certain other factors. From this and the number of airplanes for maintenance, overhaul and op-

erational protection, the total number of aircraft required is obtained.

Operating Plan

The Operating Plan is developed from the Schedule and other factors and shows the amount of flying expected to be done by the Company for the period under consideration by types of aircraft and routes. The other considerations would include percentage of the Schedule expected to be completed, non-scheduled flying both revenue and non-revenue etc.

Budget

The Budgets, both revenue and operating, are developed from the Operating Plan and the Schedule. For example, the Maintenance and Overhaul Department uses almost entirely the Operating Plan figures, whereas a station is probably more interested in the Schedule. In certain long range studies, the budgeting is done at a fairly high level and would not be sent, for example, to the stations.

The results, of course, are strictly an arithmetic summation of the Budget. They are, obviously, quite important and because of the results obtained it may be necessary to go back and alter certain things. In some cases, it may be necessary to go right back to the beginning and alter some of the assumptions. In other cases, it may only be necessary to alter some of the financing procedures; possibly the Schedule or the Frequency Pattern needs to be changed. While altering the plan to improve the results may seem to be complicated, it can usually be done quite simply provided the revisions are not too drastic.

EVALUATION OF RESULTS

After establishing the optimum plan and costs for a fully integrated fleet, assuming the DC-9 in one instance and the Vanguard in the other, a meeting was held with all Operations Department heads to evaluate the results. The following summarizes the conclusions of this meeting:

Advantages of Vanguard design

(1) Full payload may be carried either as passengers or cargo, or any combination of the two as space is available. (More flexible re cargo during off-hours for passengers.)
(2) More economical at short ranges.
(3) Wider fuselage, so six-abreast can be used under certain circumstances.
(4) Better Viscount replacement as good operational flexibility from 200 to 2,500 miles.
(5) Will definitely be built and available in winter of 1960-61 if ordered soon. (By this time Douglas had become doubtful that the time was ripe to build the DC-9 as originally hoped. At a still later date and after TCA had selected the Vanguard, the Douglas Company decided to postpone the DC-9 programme.)
(6) Lower ground noise and less fatigue problems from engine noise.
(7) Lower approach speed (10k), (25% higher max lift coeff), and better wave-off characteristics.
(8) Require fewer changes to airport facilities.
(9) Can operate fairly long haul services until traffic volume builds up sufficiently to permit DC-8's to take over service, thus enabling size of DC-8 fleet to be increased as is desirable.
(10) Better cockpit.
(11) Transition of flight crews easier from Viscounts.
(12) Easier ground handling (Sta. service & a/c).
(13) Can utilize Viscount ground power.
(14) Cost less affected by ATC restrictions and weather.
(15) Cost less affected by change in fuel price.
(16) More conventional.

Advantages of DC-9 design

(1) Faster, smoother, so greater sales appeal. (Approx. 150 mph faster.) (No vibration induced by props.)
(2) Less likelihood of competitive obsolescence. (As flying just under speed of sound, next jump must be supersonic.)
(3) More economical on long ranges (over 500 miles).
(4) Douglas Company more experienced in depth – in design, in service experience, delivery dates, airline know-how etc.
(5) Lower direct operating costs to TCA from the standpoint of common mechanical know-how and facilities.
(6) Lower indirect and maintenance capital costs due similarity with DC-8.
(7) Improved mechanical regularity due a/c and engine design and common knowledge with DC-8.
(8) More background of Avon type engine.
(9) Cheaper and easier introductory programme.
(10) Public relations advantage – more cities served by jets etc.
(11) Using equipment common with other American airlines.
(12) Common schedules times with DC-8 (e.g. Toronto-Tampa).
(13) Transition of flight crews easier to DC-8's.
(14) Reduce maintenance run-up noise problem.
(15) More choice of engines.
(16) Less possibility of interference by international situation (mid-East crisis existed at the time).

The advantages and disadvantages in delaying a decision were also discussed at the meeting and it was decided that the selection had to be made not later than November 1956, considering delivery dates required.

DECIDING FACTORS

Although most department heads probably started with a personal preference for the DC-9, in view of TCA having already ordered its blood brother – the DC-8 – after all factors had been considered and weighed, it became progressively obvious that the Vanguard was the more practical choice for the job that had to be done in TCA. The six strongest points favouring the Vanguard are as follows:

(1) *Predominant leg length*

As a result of the study of integrating the DC-9 or the Vanguard with TCA's existing fleet of Vis-

counts and DC-8's, a surprising result evolved. It was found that, considering the amount of traffic that would actually be carried by this intermediate type of airplane, its most influential flight leg length would be in the neighbourhood of 350 miles rather than over 500 miles as originally expected. This shorter predominant leg length was due to the very heavy traffic over the triangle Montreal-Toronto-New York.

The net result was that, with both airplanes carrying the same amount of traffic, a fleet of Vanguards could do it at a cost of around $8,000,000 a year cheaper than a fleet of DC-9's. This large saving in operating costs will result in lower fares and improved service being given to the travelling public than could be done with the pure jet DC-9.

(2) *High-density suitability*

The trend of traffic increase accompanied by reduced fares points to the need for a high-density passenger airplane on many relatively short flight legs. There will be a real need for an airplane capable of carrying at least 90 passengers on many flight legs initially planned for the Viscount. As these legs will generally be below 400 miles, a large-fuselage, propeller-turbine airplane will be much better able to provide these services, when needed, at a low cost.

(3) *High-density capability*

The width of the fuselage of the Vanguard is such that six-abreast seating could be installed for future short high-density flight legs and thus increase still more the economic advantage of the Vanguard.

(4) *Cargo capability*

The large capacity of the belly cargo compartments in the Vanguard make this airplane much more flexible in its ability to handle heavy cargo and mail loads at off-hours from a passenger standpoint, and thus should enhance the utilization of the airplane on the intercity services where passengers in general avoid flying between 11.00 pm and 7.00 am.

(5) *Noise*

There will be less likelihood of TCA creating a noise problem at the smaller airports with the Vanguard than with the DC-9.

(6) *Take-over from Viscount*

Another key to the unanimous decision for recommending the selection of the Vanguard was the belief that TCA will best be served by buying Vanguards for its medium range services, which airplanes will gradually take over services now planned for the Viscount as soon as traffic density permits, even to the extent of pushing a certain number of Viscounts out the bottom for sale. On the other hand, it is believed that the DC-8 will prove most capable of taking over services initially planned for the Vanguard as soon as traffic density or the need for increased speed dictates.

In this whole study, it must always be remembered that any figures quoted relate to the design of the DC-9 and Vanguard as they existed when the analysis was made. Designs are continually changing as the manufacturers make improvements to satisfy new prospective customers. Also, the study was made to determine the airplane best suited to TCA's particular fleet requirements. Other airplanes could well be more suited to the needs of other airlines.

DESCRIPTION OF THE VANGUARD

Let us now consider briefly what the Vanguard is like. The following table illustrates a few of its chief characteristics:

Span	118 ft
Wing area	1,529 sq ft
Overall length	122 ft 10 in
Height	35 ft
Ground clearance of fuselage	3 ft 6 in
Gross takeoff weight (structurally good for 141,000 lb)	135,000 lb
Landing weight	114,000 lb
Zero fuel	105,500 lb
Operational weight empty	80,000 lb
Maximum payload	25,500 lb
Space limited payload	32,000 lb
Cargo volume	1,360 cu ft
Number of passengers: 96 as two-class airplane with 50 tourist seats at 5-abreast and 46 first class seats 4-abreast	
Normal cruise speed	425 mph
Approach speed	138 mph
Ultimate range:	
with full payload	2,650 miles
with full tanks and 16,200 lb payload	3,450 miles
with no payload	3,700 miles
Fuel capacity	39,000 lb or 5,100 Imp. Gals
Type of fuel	JP4 (wide cut gasoline)
Powerplant	Rolls-Royce Tyne RTy1, producing 4,500 shp, 5,000 eshp
Normal cruising altitude	20,000 ft
Cabin pressure	6.55 psi or 8,000 ft in the cabin at 30,000 ft alt
Runway takeoff length	6,200 ft
Runway landing length	5,500 ft

The Vanguard is very definitely not a blown-up version of the Viscount but it is a completely new design from scratch, based upon the experience that Vickers-Armstrong has gained from the Viscount turbo-prop operations throughout the world.

Description of the Tyne

The heart of any airplane is its engine. The Rolls-Royce Tyne, like the airplane, is a new design based on the years of experience of operators throughout the world with the smaller Rolls-Royce Dart propeller turbine engine. The design of the Tyne was started in

1953 and the first engine was run in the spring of 1955. Improvements to the design have been made continually since that time as greater experience was gained with Darts and Avons. The Tyne will start commercial operations with three times the power of the Dart and 40% lower specific fuel consumption.

The Tyne comprises:

Ten small combustion chambers

A single-stage high pressure turbine, driving a nine-stage high pressure compressor

A three-stage low pressure turbine driving a six-stage low pressure compressor and a propeller reduction gear which drives the propeller at 0.064 times the low pressure shaft speed.

Cooling of the turbine blades and nozzle guide vanes is an outstanding feature of the design.

The first and second stages of the low pressure compressor rotor and stators are heated by compressed air for de-icing. Intake duct struts are heated by oil for de-icing and the leading edge of the cowling is de-iced by electric elements.

The engine is controlled by a simple, single lever with no "black box".

Water is not required for takeoff under hot day conditions.

DELIVERY DATES

In conclusion, it might be of interest to mention that Vickers expect to fly their first Vanguard this fall, with the completion of Certificate of Airworthiness flight trials eighteen months later. They expect to have six airplanes ready for delivery to BEA when the C. of A. is granted around March, 1960. BEA have twenty Vanguards on order with an option for five, and TCA has an order for twenty with an option for four.

Because of the magnitude of the training involved in introducing the DC-8's into TCA's fleet early in 1960, TCA will not be able to take delivery of Vanguards until near the end of that year. TCA expects to operate its 1961 summer service with a combined fleet of twenty Vanguards, six DC-8's, fifty-one Viscounts and no reciprocating engined airplanes. This, we believe, will be the first all-turbine fleet in the world.

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THE DOPPLER SENSOR IN AIR NAVIGATION†

by K. C. M. Glegg*

Canadian Marconi Company

A YEAR or two ago, an instrument called a Doppler Sensor might easily have been taken to be a device intended to contact the now long-departed spirit of John Christian Doppler. Today, we all know, of course, that a Doppler Sensor is a device which has captured the spirit of Herr Doppler in a rather more useful, if less tangible, way.

As is now quite well known, the Doppler Sensor is directed at making the dead reckoning process in air navigation more accurate. The essentials of this process are found in the classical velocity triangle shown in Figure 1. The object of this process is, of course, to find the magnitude of the groundspeed and the direction of the track. Evidently, four quantities are required, namely:

(i) wind speed
(ii) wind direction
(iii) true airspeed, and
(iv) heading.

Since there are doubtless meteorologists or their friends in the room, it will suffice for the moment to say simply that some of these four quantities are generally known with better accuracy than others, and that the net result is an estimate of groundspeed and track which is not sufficiently accurate for present-day navigational requirements.

What then does the Doppler Sensor do? Briefly, one may say that it makes a direct and relatively very accurate measurement of groundspeed and drift angle which may be substituted for knowledge of the first three of the above four quantities, leaving one dependent only on the additional knowledge of heading in order to carry out the dead reckoning process. The new situation is given in Figure 2, which shows that track is obtained simply by adding the directly measured drift to heading, with groundspeed a directly measured quantity as indicated previously. In fact, if use is now made of true airspeed, it becomes possible to calculate the wind velocity with an accuracy considerably better than had previously been available, but this is not strictly a part of the dead reckoning problem. It is worthwhile observing here that all the equipment for making the measurements is confined to the aeroplane. No ground

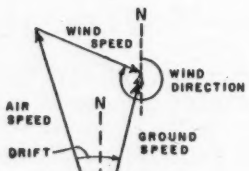


Figure 1
Classical velocity triangle

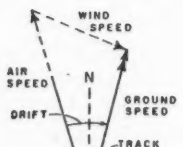


Figure 2
Doppler velocity triangle

facilities of any type are required and so the device is completely self-contained.

My primary object, of course, is to talk about the errors which are characteristic of a Doppler Sensor. With the foregoing as a sketch of where this instrument fits into the navigation scheme, I should like now to outline briefly the method of operation of a typical Sensor system so that there will be enough background to provide a suitable picture when discussing errors.

How, then, does a Doppler Sensor work and what does it consist of? Figure 3 serves to introduce the essentials. The aircraft carries a microwave transmitter and receiver. Working with a suitable antenna the transmitter radiates a frequency, say F, toward the earth, the radiation being confined to a narrow beam by means of the antenna.

The earth reflects a portion of the radiation back to the receiver which receives a frequency $F + f$. The difference, f, between the transmitted and received fre-

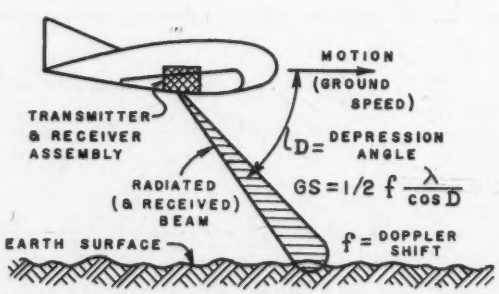
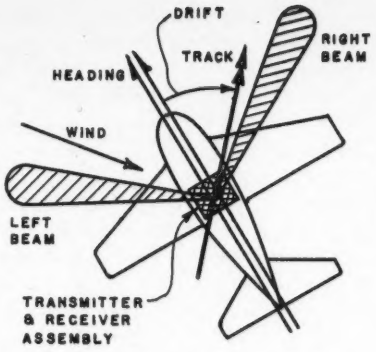


Figure 3
Sensor essentials

†Paper read at the Mid-season Meeting of the C.A.I. in Vancouver on the 28th February, 1958.

*Special Assignments Engineer.



BEAMS IN ZERO POSITION SYMMETRICAL ABOUT AIRCRAFT FORE AND AFT AXIS

Figure 4
Drift measurement: start

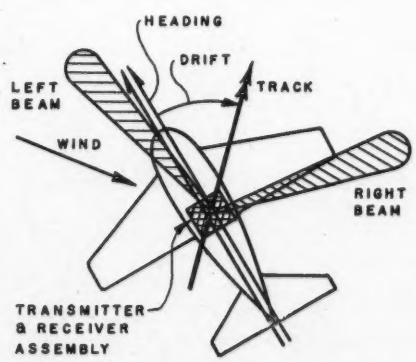
quencies is, according to the theory of the Doppler effect, a measure of the groundspeed of the aircraft, the exact relation being given in Figure 3. Representative numbers would be: wavelength 3 cm, depression angle 70°, shift = 2 Kc/s, groundspeed = 175 kts. The foregoing assumes that no drift is occurring. Figure 4 shows, however, how drift is measured.

To measure drift, two beams are radiated, one to the left and one to the right, both, of course, depressed toward the earth as for groundspeed measurement.

The drift system is permanently zeroed on the ground with the antenna positioned so as to radiate the right and left beams symmetrically about the fore and aft axis of the aircraft.

When, in flight, wind causes the aircraft to drift, say, to the right, the track will be closer to the right than to the left beam. As a result, the component of groundspeed sensed by the right beam will be larger than that sensed by the left beam, and so the Doppler shift in the right beam will be larger than that in the left beam.

The next stage in the operation is shown in Figure 5. Here, the antenna has been rotated until the Doppler shift in the left beam is equal to that in the right beam, in which condition the beams are symmetrical about the track. The angle through which the antenna is turned from its zero is, clearly, the drift angle.



BEAMS AS POSITIONED IN FLIGHT, SYMMETRICAL ABOUT TRACK.

Figure 5
Drift measurement: finish

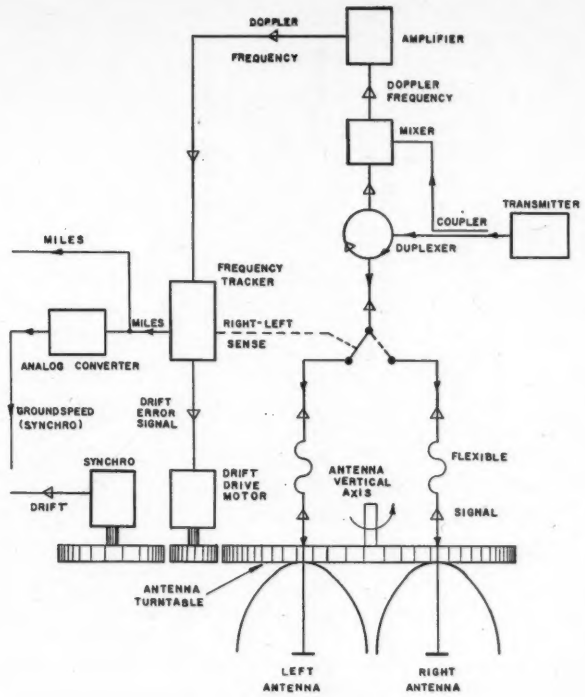


Figure 6
Block diagram of Sensor

In flight, the antenna is automatically rotated to keep the beams symmetrical about the track, so that, assuming proper zeroing, the angular position of the antenna gives a continuous and direct measure of drift. Under these conditions, the Doppler shift in either beam can be used as a measure of groundspeed, even when drift is occurring. Figure 6 shows a block diagram of a Sensor of the type outlined in the foregoing.

With this much background it should now be possible to get down to the business of errors associated with a Doppler Sensor. The sources of error are divided into three groups as follows:

(1) aircraft sources of error,
(2) external sources of error, and
(3) actual Sensor sources of error.

As might be expected, it will develop that these sources are not entirely independent, but the above grouping will, nonetheless, prove quite useful in the following discussion.

AIRCRAFT SOURCES OF ERROR

The error sources in the aircraft can be divided into two general types, namely aircraft rotation and aircraft translation sources. In the rotation group there will be pitch, roll and yaw and in the translation group there will be climb. As it happens, it is very convenient analytically to combine the effects of pitch and climb and the aircraft error sources will, therefore, be treated as

(a) pitch and climb,
(b) roll, and
(c) yaw.

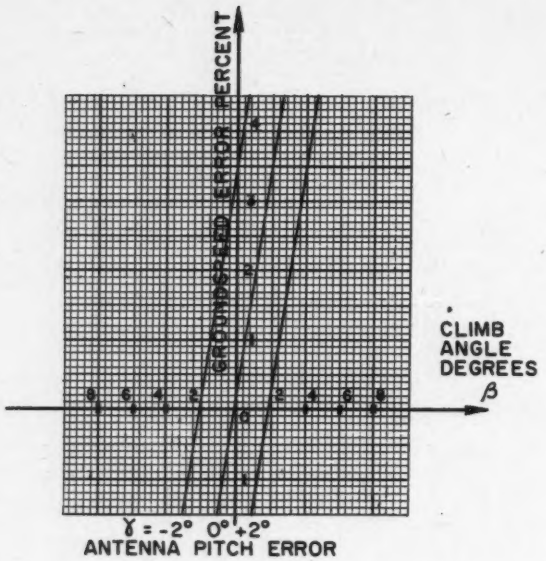


Figure 7
Single ended pitch and climb error

Pitch and Climb

Looking at the problem on a purely common sense basis for the moment, it is evident from Figure 3 that the accuracy of the system will be relatively poor because both pitch and climb have the effect of changing the effective value of the depression angle *D*. Quite straightforward analysis of the situation shows that the groundspeed error in per cent is about twice the difference between the climb and pitch angles in degrees. This is shown as a graph in Figure 7. These errors are, of course, quite large (even if the antenna is kept horizontal by stabilization) and must be reduced in some way. Possibly the most satisfactory way of bringing this error within tolerable limits is to use, in addition to the forward pair of beams, a backward beam or a pair of backward beams. Figure 8 shows a side view of this arrangement, and Figure 9 is a plan view. In such an arrangement, the Doppler shift in the left front beam is added to the shift in the right rear beam and this sum shift is taken as a measure of the groundspeed. The same is done for the other two beams. Drift operation is the same as with just two beams, but using the two sum frequencies instead of the two single frequencies. This simultaneous use of forward and backward looking beams is frequently called Janus operation.

Figure 10 shows the new per cent groundspeed error due to pitch and climb, with the error for the previous type of system shown dashed for comparison. Evidently, if the antenna is now levelled with an accuracy of $\pm 1°$, combined pitch and climb errors will not exceed 0.25% for climb angles of $\pm 10°$.

Roll

In order to appreciate the nature of the roll error, it is simplest first to consider the situation in which no drift exists. If, under these conditions, the aircraft rolls, the beams will move over the surface of a cone which has the velocity of the aircraft for its axis. The point to notice here is that since with roll the beam continues to make the same angle with the velocity of the aircraft as with no roll, the frequency shift for a given groundspeed will not change. Thus there is no error, either in drift or groundspeed, due to roll when there is no drift.

When there is drift, the situation is a little different, because the roll is no longer about the axis of the antenna. The roll must, therefore, be resolved into a component about the axis of the antenna which yields no error, and a component normal to the axis of antenna which is simply a pitch error. For a drift angle ρ and a roll δ the pitch component is simply

$$\rho \sin \delta$$

when ρ and δ are not too large. It is, therefore, possible to use the graph of Figure 10 to give per cent groundspeed error if the above expression is used to convert the roll to the effective pitch angle of the antenna for, say, the maximum drift.

Since large roll angles do not normally persist for long periods, it is evident that extremely small errors (less than 0.1%) would normally result from aircraft roll.

Yaw

Yaw will, in general, cause no error in groundspeed, since the Doppler Sensor will simply record yaw as drift, which is, indeed, correct when it is combined with the heading output of the aircraft compass to produce track. Notice, however, that a wind computed from a yaw angle reported as a drift angle is not correct.

These make up the sources of error which can, in our sense, be attributed to the aircraft. Summarizing the

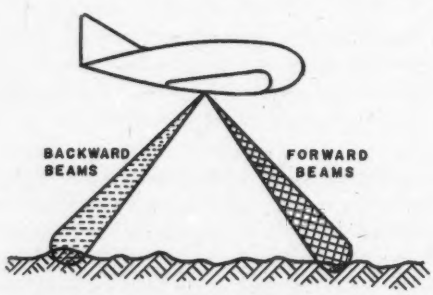


Figure 8
Janus arrangement (side view)

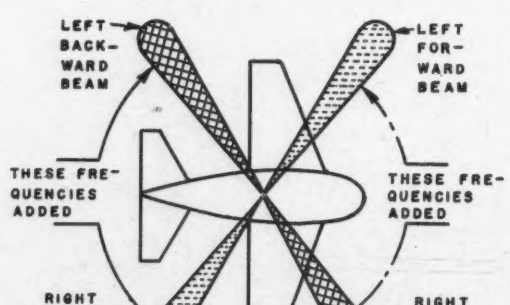


Figure 9
Janus arrangement (plan view)

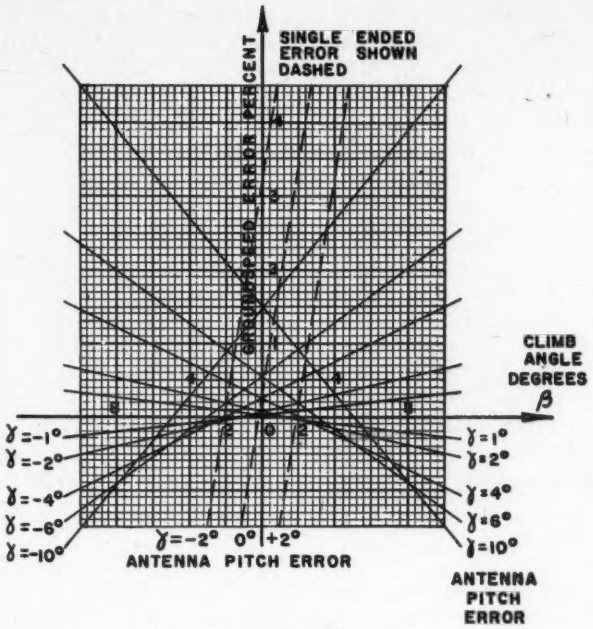


Figure 10
Janus pitch and climb error
(single ended error shown dashed)

results, it appears that, with Janus operation, it is possible to obtain groundspeed accuracies of the order of 0.25% in the climb phase, and considerably better than this in more or less level flight when normal conditions exist. "Normal" here has essentially an airline connotation, since the military connotation has somewhat more ramifications than can be treated here.

Next on the list of sources of error are external sources and these will now be discussed.

EXTERNAL SOURCES OF ERROR

The external sources of error can be divided into three general types, namely

(a) land,
(b) sea, and
(c) cloud.

Land

As it happens, the reason for including the land as a source of error is not because there is actually any known error source associated with the land, but because there exists such a strong superficial tendency to believe that there should be such an error. Usually, this very strong tendency manifests itself in a question, such as "what happens when the airplane flies over a hill? Does the slope of the hill affect the accuracy of groundspeed measurement?" I was once told by an engineer from a well-known electronics firm that it was the wrong answer to this question that prevented his firm from ever trying to make a Doppler Sensor many years ago. As it turns out, of course, this sort of terrain irregularity does not affect the accuracy of the groundspeed measurement.

This very important result is due to the fact that the scattering process, which yields the wave reflected back to the airplane, is a quite random one, both space and time-wise, with the consequence that extensive slopes, such as hills, are lost in the essentially noiselike character of the signal. For an error to result, it would be necessary for the scatterer to be smooth on the scale of the transmitted wavelength over the extent of the area illuminated by the beam. This, at a wavelength of 3 cm, is for all practical purposes impossible.

This might sound like very wise doctrine, but the professional navigator, as well as the engineer, will want to know if anyone ever checked all this. The answer, fortunately, is yes, and even if we are right for the wrong reason, it appears that we're right.

So much then for the land and an error that might have been.

Sea

Next on the list of external sources of error is the sea, and here we find sources that might have been worse and some that might have been better. There are four sources of error associated with the sea as follows:

(i) wave motion,
(ii) wind driven spray,
(iii) currents, and
(iv) scattering effects.

The errors associated with wave motion appear to be very small and have not, to the best of my knowledge, been conclusively demonstrated. This allows one to say that they are, in all likelihood, below 0.25%. The reason for this is due to the fact that wave motion does not of itself lead to any mean flow along the surface. Thus, waves would tend to make the measured groundspeed value oscillate slightly, but should have little effect on mean groundspeed and virtually no effect on computed position.

The effects of wind-driven spray are, however, not negligible. Here the effects appear to amount to about 10% of the surface wind. It is quite easy to see why the effect on groundspeed should only be a small fraction of the surface wind, since in the presence of spray the reflections still tend to come from the water surface below the spray with a relatively small reflection occurring from the spray itself. Thus, the measured groundspeed tends to be weighted only slightly toward the value which would be measured if the wind-driven spray were the only reflector. If no attempts are made at correcting for this effect, groundspeed errors of as much as 6 kts would result when flying over areas with surface winds of 60 kts. If the 60 kt surface winds were at right angles to the track, there would be primarily a drift error, which will vary inversely with the groundspeed and which would amount to about 1° for a groundspeed of about 200 kts.

The third source of error associated with the sea, the scattering error, is somewhat more obscure than either of the previous two. We can get at the reasons for the error via Figure 11, which shows the dependence of the backscattered power on the angle of incidence which a transmitted beam makes with either land or sea. A number of features of these errors are of interest. First, the scattering from the land is essentially independent of angle as indicated by the two horizontal lines. In contrast

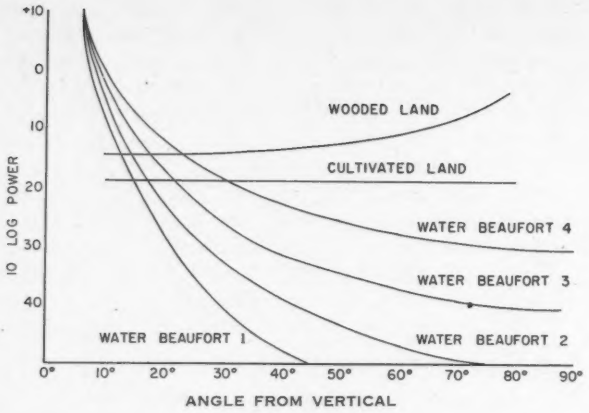


Figure 11
Scattering coefficients for land and water

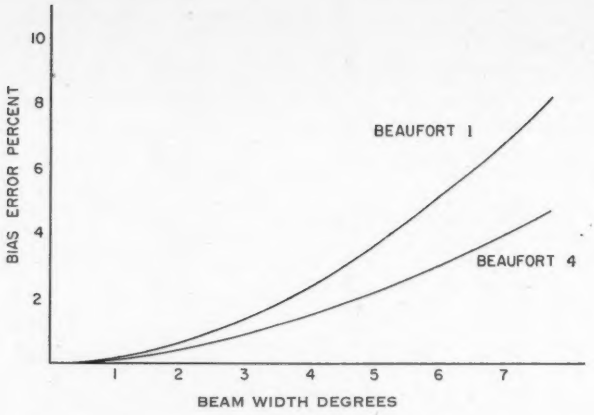


Figure 12
Doppler velocity water bias error vs one-way beam width for a depression angle of 69°

with this, the scattering from the sea varies quite drastically with the angle of incidence and, furthermore, the rate of variation depends upon the sea state. The groundspeed error mentioned previously comes about as follows. Since over the land the scattering is independent of incidence angle, the depression angle associated with the transmitted beam can be taken to be the angle associated with the direction of maximum intensity in the beam, which can be very accurately controlled. However, over the sea, the angular dependence of the backscattering tends to weight the effective intensity maximum toward the vertical and so the effective depression angle is increased; that is, the Doppler shift associated with a given groundspeed becomes lower over the sea than over the land. This would be trouble enough, but to add a little further complication the amount by which the shift is lowered for a given speed is dependent on the sea state.

Figure 12 summarizes this situation and shows not only how the groundspeed error depends on sea state, but relates the effect to the actual width of beam transmitted for a quite typical depression angle of 69°. These, incidentally, are calculated errors, based on the data in Figure 11.

It appears that for beam widths between 3° and 4°, which are quite typical, errors between 1% and 2% are to be expected over the more likely range of sea states.

The procedure adopted in the design of many Sensors is, therefore, to include a so-called "land-sea" switch, the function of which is to change the groundspeed calibration by about 1.5% when the aircraft is over the sea. This leaves a possible error of about 0.5% in groundspeed, depending on the sea state.

It should be noticed that since the determination of drift requires only that the right and left frequencies be equal, there is no drift angle error associated with scattering effects over the sea.

The sea scattering error is almost certainly the most serious and troublesome error associated with a Doppler Sensor, since the error is a persistent fixed percentage and the continuing increases in aircraft speed do not minimize the problem as is the case with, say, wind driven spray, which is simply a comparatively rare maximum error of 6 kts.

Cloud

We come now to the last external source of errors – clouds. In this area, there appears to be a lack of both reliable analysis and adequate measurements. Certainly there do exist cloud conditions which might be expected to cause errors, but these conditions are not expected to be either very frequent or very extensive. This expectation appears to be borne out by the now rapidly accumulating mass of experimental data on Sensors, but it does appear that anything approaching a final opinion on the point will have to wait for about another year. Essentially, the same situation exists for the effects of rain as for clouds – simply more experimental results are required.

ACTUAL SENSOR SOURCES OF ERROR

There are five main sources of error which stem from the Sensor itself. These are as follows:

(a) Beam Geometry
(b) Transmitter Frequency Control
(c) Tracking
(d) Groundspeed Analog; and
(e) Installation

Beam Geometry

There are two quantities which, between them, tell most of this part of the story. The first is 4.5% per degree which is the error rate associated with a typical depression angle of about 70°, and the other is 0.1° which is the general order of economically practical manufacturing accuracy for the antenna system. It appears, therefore, that one might expect beam geometry errors of about ± 0.4%.

It should be noticed that this is generally a permanent error built into the antenna and can be removed by a calibrating procedure, which is sometimes done more conveniently at the factory but is sometimes done in the aeroplane.

Transmitter Frequency Control

This might at first sight appear to be a problem, since the Doppler shift is inversely proportional to the transmitted wavelength. However, two solutions exist. The

first, which is frequently quite feasible, is simply to use an oscillator with a stability of, say, 0.1%, which is not too difficult to obtain. The second solution relies on designing the antenna such that the frequency sensitivity of the depression angle just balances off the effect of the frequency change itself. This error, then, need not exceed about ± 0.1%.

Tracking

Before discussing tracking errors, it would doubtless be of some value to point out that there is a very real sense in which it is possible to say that the basic quantity measured by a Doppler system is the distance moved, rather than the velocity of motion. This can be readily appreciated, since if the Doppler frequency is proportional to the speed, then the number of Doppler cycles which occur in a certain time will simply be proportional to the distance travelled in that time. As is well known, it is possible to build essentially error-free cycle counters and so the number of Doppler cycles occurring in some interval can be counted with an error remaining only in the measurement of the time interval.

Since one of the recurring questions in dead reckoning is "How far have I gone since I started?", the number of Doppler cycles that have occurred since starting are of direct interest. Stated somewhat differently, it would be sufficient simply to count Doppler cycles and not worry about the actual Doppler frequency at all.

What we have done by this line of argument, of course, is virtually to arrive at the definition of that essential part of a Doppler Sensor known as the tracker. It is, in fact, the part which takes in the so-called "raw noisy Doppler" from the receiver and puts out a cleaned-up and frequently counted down version that is essentially noise free. The output of the tracker is then simply total ground miles flown, unresolved as to direction.

The question now relates to the errors that are usually committed in the tracking operation. This, as it turns out, can be made a relatively accurate process, errors being kept generally well below 0.1%.

Groundspeed Analog

A groundspeed output, whether in the form of a pointer, synchro, shaft-driven counter or other type of instrumentation, will always rely fundamentally on an analog conversion from the tracker, since there exists the basic dimensional problem of going from (miles per hour) per (cycles per sec) to (miles per hour) per (degree), say, in the case of a rotating pointer.

It can, therefore, be stated quite generally that the per cent error in a groundspeed pointer (or shaft-driven counter) will always exceed the per cent error in the tracker miles output. With reasonable care, it is possible to keep this analog transfer error at about 0.5%.

This suggests that for computing present position it would be more accurate to use the tracker output rather than, say, the ground speed pointer output, and this is in fact sometimes done.

Installation

The main source of error in the installation process is associated with ensuring that the zero reference for the drift system and the aircraft reference for the compass system coincide. With care, this can be held to about 0.25°.

This completes the rather long list of errors which are associated with this device. My hope is, however, that the multiplicity of the errors will not obscure their smallness, but rather convey the very considerable amount of thought and work that have gone on in many parts of the world in order to make possible the really quite remarkable instrument which we now have in a Doppler Sensor for air navigation.

ELECTRONICS AND TRANS-CANADA AIR LINES†

by C. J. Campbell*

Trans-Canada Air Lines

During the years of my association with aeronautical electronics, both Military and Civil, it has been said repeatedly that electronics is the "nerve" system of airborne operations. The role of electronics has been constantly increasing in importance in this field. Nor is the application of electronics any longer confined to airborne operations; electronics are being used widely in airline reservation systems, airline accounting systems, logistics and for scheduling and planning the operation of airlines. I would like to review briefly the various electronic systems employed by TCA and to cover in greater detail a few of the electronic systems recently developed and likely to be incorporated in our operations.

Before World War II, when we thought of aeronautical electronics, we probably envisaged a simple air/ground communications channel on low, medium or even high radio frequencies and probably some point to point communications, again employing low, medium or high radio frequencies and radio telegraph techniques. The only electronic assistance to aerial navigation in general use by the scheduled airlines was the ADF receiver, again employing low and medium radio frequencies. Prior to 1945 we can, therefore, envisage a scheduled aircraft carrying dual LF/HF receivers and transmitters, of possibly 10 channels each, and dual ADF receivers to indicate bearings from low frequency ranges, low frequency radio beacons or broadcast stations.

The great increase in airborne operations following the war created new problems of safety and air traffic control which could only be met by increased and improved communication and navigational aids.

The rapid increases in the VHF and UHF fields during World War II did much to improve the effectiveness of electronics for civil aviation and it might be interesting to review the various electronic systems now used in our long range aircraft.

AIR/GROUND COMMUNICATIONS

HF/Transmitters/ Receivers	100 watts radiated power 144 discrete channels 2 – 22 mc/s
VHF/Transmitters/ Receivers	25 watts radiated power Up to 360 discrete channels 118.0 – 135.9 mc/s – 50 kc spacing

INTERCOMMUNICATION

All aircraft are provided with transistorized intercommunication facilities to permit signalling and discussion between all crew members.

NAVIGATION

Dual ADF receivers	150 kc – 1750 kc
Dual VOR receivers	108 – 118 mc/s
Loran receiver and indicator	Long range hyperbolic navigation system – 2 mc/s, 300–1,000 nautical miles
Radio altimeter	Pressure pattern flying. Difference between absolute and pressure readings referred to charts.
Marker receiver	Operating 75 mc/s and indicates by lights when the aircraft passes over locations of ground transmitters.
ILS Receiver	Indicates lateral reference to runway. Glide Slope – provides vertical glide angle reference. Marker Beacon – indicates distance from runway at 2 or 3 points on approach.
Dual Gyro Magnetic Compasses	Usually mounted on wing tip or tail in area free from magnetic disturbances and can be kept accurate to approximately 1°.
Magnetic Compass	For standby
Sextant	Provides altitude and azimuth of stars, sun or moon, from which position relative to earth can be determined from charts.
IAS and Temp or TAS	These systems are not very accurate; of the order of 2 to 5%.

WEATHER AVOIDANCE

All modern aircraft are being equipped with nose weather radar to enable the pilots to avoid areas of thunderstorm activity, heavy precipitation and turbulence.

†Paper read at the Mid-season Meeting of the C.A.I. in Vancouver on the 28th February, 1958.

*Director of Telecommunications.

POINT TO POINT COMMUNICATIONS

Until about three years ago, most of our routine point to point traffic was handled via teletype, using the "torn tape" relay method. This involved our traffic arriving at Switching Centres where the individual messages were torn manually from the tape and inserted manually on the appropriate circuit for delivery. We replaced this manual system with a Western Union Plan 54, semi-automatic teletype switching system. With few exceptions, this system serves all our domestic and U.S. stations and eliminates the need for any manual relay of our point to point traffic. An operator at the Switching Centre simply reads the address on the teletype tape and presses the appropriate button or buttons to direct the message to the address or addresses concerned. The semi-automatic system has been very satisfactory and, besides resulting in a considerable reduction of personnel, has speeded up our message handling time to where we can now expect 5 minute service from any point on our system to any other point so served. To give some idea of the volume involved, we handle some 40,000 messages per day on the domestic system.

Some four years ago, with the increased speed of our aircraft and the increased number of aircraft in our operations, we found that in many cases written communications were too slow for the efficient operation of the airline and we installed two private, long line telephone circuits, from coast to coast, one for reservations and the other for operations. These of course were in addition to the teletype circuits previously discussed. Despite the high cost of these facilities, we are convinced they pay their way in tangible savings, improved efficiency and service to the travelling public.

For communications between Canada and Europe, we have recently leased a teletype channel in the new trans-Atlantic telephone cable between Montreal and London and, needless to say, the service on this facility is excellent. Our traffic to and from other European points is relayed at London and handled on leased commercial aeronautical circuits.

We also participate in a shared aeronautical teletype network serving Florida, from where our traffic to and from the points we serve in the Caribbean is relayed. Similarly, we participate in a shared aeronautical teletype channel between New York and Bermuda.

TCA maintains a ground radio station at each domestic station we serve. These are principally VHF stations for air/ground service but high powered HF installations are also provided at our main Flight Dispatch Centres. These are required for direct communications with our aircraft in flight for company operational control purposes, but we do provide service to other scheduled, non-scheduled and itinerant operators with these facilities, under contract. At the present time we have contracts with 29 other operators for such service. These ground radio stations are designed for unattended operation and are maintained from the Telecommunications Shop at Dorval. We also maintain a fully equipped Telecommunications Laboratory at Montreal, concentrating principally on airborne equipment problems.

NEW DEVELOPMENTS

Communications

At present the trend is to VHF air/ground communication for domestic service but, of course, high frequency is required for international communication. Much effort is being exerted to increasing the reliability of these equipments and to reducing their size and weight. Excellent progress is being made in these fields, as indicated by the fact that the high frequency communications equipment in our Super-Constellation aircraft weighs 457 pounds – that in our DC-8 will weigh 196.5 pounds. Similarly, the VHF installation in the Super-Constellation weighs 78 pounds – that in the DC-8 will weigh 48 pounds.

New developments in the application of Single Side Band communications are being followed with interest but no early implementation of airborne equipment utilizing these principles is foreseen. Automatic data transfer is also being actively investigated and will be evaluated in the very near future.

Airborne Radio Teletype

For some three years TCA and BOAC, on behalf of the majority of North Atlantic scheduled airline operators, have been evaluating airborne radio teletype for the reception of ground to air communications in the trans-Atlantic region.

As you are aware, this is a particularly difficult region for the propagation of high frequency radio communications. When we moved from WT to RT operation in the area in 1954, it became quickly evident that RT, despite its other operational advantages, was not a good medium for the handling of the large volume of one-way, ground to air communications, particularly meteorological information. Such meteorological information and flight advisory messages are actually required in written form to be of maximum value; for example, such information is often transmitted from the ground to the aircraft when the crew are busy with other duties and not in a position to physically copy it. These requirements led to our investigation and we now have low frequency broadcasts on frequency shift radio teletype made from one station on the east coast of Canada and one station in Scotland.

This development has proven very reliable and satisfactory in all respects. Continuous overlap is provided in the centre of the Atlantic by the two ground stations, even during periods of HF blackout, and we are convinced that there is certainly a future for this service, particularly in that area. We have provided for this equipment in our future trans-Atlantic aircraft and other North Atlantic airlines are now equally interested. The technical evaluation of the system is complete and all that remains is an operational evaluation to determine what types of traffic can best be handled on this medium.

Navigation

At present a large number of new navigation devices and systems are under development and evaluation in the industry, some of which are:

TACAN
VORTAC

ATC Beacon
Decca
Dectra
Navaglobe-Navarho
Cytac
Doppler Navigation
Inertia Navigation

I regret to say that in my some twelve years' association with civil aviation we have not removed one single communication or navigation service from the aircraft, although we have installed systems which are lighter and more compact than the original. It is evident, however, that we cannot continue to install system after system in our aircraft at the expense of payload. At the same time, we have aircraft on order which will be flying at speeds between 500 and 600 miles per hour in 1960. This increases the ATC problem drastically and emphasizes the need for the more accurate maintenance of given tracks. Of the above systems, the Doppler is a self-contained system which shows great promise of providing us with accurate information without depending on ground installations. We are presently evaluating a Canadian Marconi Company Doppler system which in itself provides us with ground speed and drift angle directly. We do require some further computations before we can depend on this system solely and Computing Devices of Canada Ltd. have provided us with a small electronic computer for this purpose. The combined units are installed in one of our Super-Constellation aircraft and the system evaluation will be completed during the next few months. It is our sincere hope that this system may eliminate some of the duplicate systems we must carry today and, in addition to saving us payload, it will provide us with greater accuracy and reliability, anywhere in the world, than the various combinations we now have to use.

Automatic Reservations

We have been concerned for many years with improving our reservations service, both from the point of view of offering a better service to the public and of filling those empty seats which so often appear at the time that the flight departs. The inherent slowness of communications across a system as wide-spread as ours is certainly an important factor and, some four years ago, we in the Telecommunications Department were asked to investigate this broad problem. It soon became apparent to us that a satisfactory reservations system must, in addition to keeping the seat inventory always up to the second, provide continuous statistical information to enable us to better plan our procedures, schedule times, size of aircraft etc. We reviewed the systems being developed in the United States and Europe and felt that while they might do a satisfactory job of keeping the inventory they were not designed to provide the statistical information we needed so badly for planning purposes. Accordingly, we had an outside study undertaken, following which we raised a development contract with Ferranti Electric of Toronto. To make a long story short, we jointly developed what we consider to be a very satisfactory solution to this large problem. The system is built around "agent sets", which we have called Transactors, and I will outline to you briefly how the system operates. The Transactor is a mark sense device which reads pencil marks made on a card which is inserted therein. It is interesting to note that the device is a "static" card reader and that no electronic or mechanical scanning of the card takes place. The card is firmly clamped when it actuates the microswitches at the base of the slot and marks are detected by some 300 precious metal reading heads built into the face plate of the slot. Marks so detected are converted by a coupler to a high speed binary code, which is transmitted by a telephone circuit to the central electronic computer in our Reservations Centre. The computer makes the search as instructed by the marks and transmits a reply which results in the card which was originally inserted being punched. The card becomes the local record and, of course, if the space is later cancelled the same card is located in the file and a cancel mark drawn through the instruction "cancel". The card is inserted again into the Transactor and the computer removes the original sale from the inventory and punches the card "cancelled".

The operation is designed to handle transactions during peak periods in a maximum of 3 seconds. For any transaction made anywhere on the system a record is maintained at the computer, either in the form of punched cards or on a magnetic tape, so that statistical information is readily available as required. It is interesting to note that the system is not limited to simple inventory control nor, in fact, to airline reservations. I prefer to think of the system as a general purpose business transactor rather than a specialized reservations system and we have been careful to build in the necessary flexibility to insure such is the case. For example, it will be necessary on many occasions to change our procedures and this can readily be accomplished in this system by simply reprinting the card and reprogramming the central computer. Cards are provided for "reading in" flight arrival and departure information. Once this is done, any Transactor on the system can secure the latest information immediately. Control cards are provided so that seats in flight can be added or removed as required. Manifest or load information can be inserted by means of a card and this same information read by any Transactor on the system when required. This system as it now stands appears to meet fully the needs of TCA in the reservations field and, while plans for its production are far from complete, there is a possibility we may first install a prototype installation on the Vancouver-Victoria-Seattle routes.

I would also like to mention that our Comptroller's office will shortly be installing electronic computing systems for inventory control, payroll calculations and various report functions.

CONCLUSION

In conclusion, I am sure you will agree with me that it can truly be said that electronics are finding a very important place in every department of the airline and that the trend towards the use of electronics in the airline business is certainly on the increase.

INVESTIGATION OF A JET MUFFLER MODEL†

by S/L A. J. Campbell*

Royal Canadian Air Force

SUMMARY

A wide angle diffuser for reduction of the noise of a jet, by taking advantage of the AV^8 law, was combined with a short length augmentation system, which, on a full scale muffler, would provide cooling air flow to the diffuser.

A large reduction in velocity and a small cooling air flow were attained when screens were used to prevent separation of flow in the diffuser. The experimental results, when compared with current literature, indicate that grids of rods or pipes (which could be cooled internally) would also provide satisfactory resistance. However, the experiments, which may not be representative, indicated a pronounced noise augmentation when rods were used.

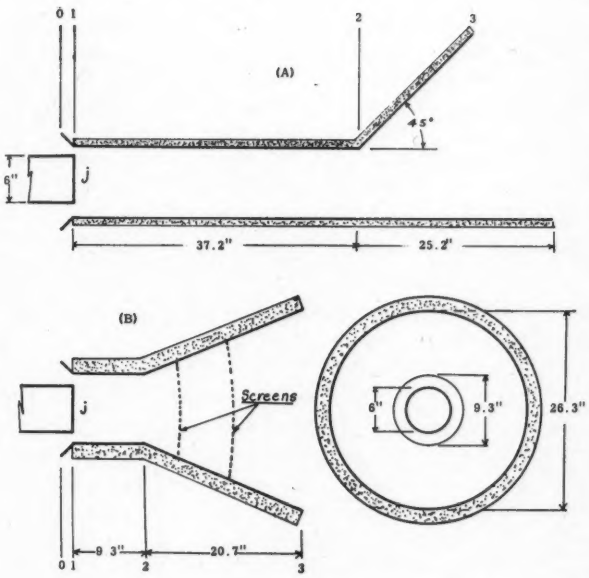
In the frequency bands which are of interest, the noise level of the model was higher than that of the free jet. However, the main noise source was found to be inside the muffler. It appears to be possible to reduce its output by aerodynamic means, and further to decrease the radiated sound by acoustic treatment.

INTRODUCTION

A MODEL of a muffler design for ground running of jet aircraft was tested for aerodynamic and acoustic performance. There were two main considerations in the design: first, to reduce the jet noise intensity, which varies as the velocity of the jet to the eighth power, by expanding the jet to a large cross section and a low velocity; and second, to provide cooling air flow so that material used in the muffler would not have to be highly heat resistant. For reasons of economy it would be advantageous to keep the size as small as possible. It was expected that the muffler would produce a great deal of noise internally; therefore, some means of absorbing this noise must be included in the design.

In keeping with these considerations, an air augmentation system with a very short mixing length was selected which used a wide angle diffuser to decelerate the flow. Because of the short mixing length, any resistance used in the diffuser of a full-scale muffler to improve its performance would be subjected to a high temperature, especially along the centre line of the jet. Therefore, the use of rods (which could be pipes containing cooling flow) in place of screens appeared attractive.

Initially an asymmetric design was tested which did not perform satisfactorily, i.e. the flow was separated. A symmetrical model was then built so that the effect of a wide angle diffuser, when used on an air augmentation system, could be studied separately from the problem of flow in an asymmetric diffuser (Figure 1). Finally screens were used when the rod patterns which were tried failed to eliminate flow separation in the diffuser. Thus the investigation was an extension and combination of the work on wide angle diffusers[1, 2, 3] and on air augmentation systems[4, 5, 6].



A_j ft.^{2}	$A_{1\text{-}2}/A_j$	A_3/A_2	$A_0/A_{1\text{-}2}$
0.79	2.40	8.0	2.25

Figure 1
Muffler models (A) Asymmetric (B) Axially symmetric

Two basic designs of air augmentation are available: constant pressure and constant area mixing lengths. The constant area system is employed herein. This system is shown in Reference 7 to be theoretically better, especially when a low efficiency diffuser is employed.

LIST OF SYMBOLS

A	area
d	diameter
p	pressure

†Received 10th March, 1958.

*Logistics Coordination Staff, Air Materiel Command Headquarters.

q	dynamic pressure
u, V	velocity
x	distance measured downstream along centre line of jet axis

Subscripts

A	atmosphere
j	jet
0, 1, 2, 3	stations on model
s	static

TEST FACILITIES

Air was supplied by a 10 hp blower through a settling chamber to a six inch diameter axially symmetric nozzle. The maximum velocity of the jet was 213 ft/sec.

The asymmetrical and symmetrical muffler models were of similar design. In both, the ratio of mixing-tube area to jet-cross-section area was 2.4, the total included angle of the diffuser was 45°, and the expansion ratio was 8. The walls were 22 gauge perforated metal sheet (32½% open) with a 2 inch thick outer covering of Fiberglas. The rods used were 3/16 inch diameter steel. The screens were 30 meshes per inch of 0.013 inch wire giving a solidity or blockage of 63%. The screens were attached to the wall simply by bending the outer edge of the screen so that it formed a flange and bolting the flange to the diffuser downstream of the screen. There was some slack in the screen.

An existing constant area duct 8 inches by 12 inches was used to determine the resistance coefficient of the grids and screens which were used in the muffler.

Conventional static and total pressure probes were used to make traverses across and along the length of the model. A micromanometer capable of measuring to 0.001 inch of water was used for all aerodynamic measurements. A General Radio Sound Level meter, an

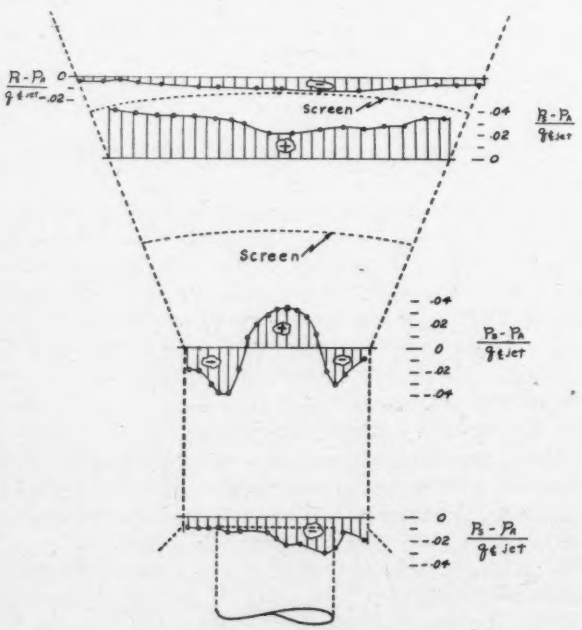


Figure 2
Static pressure profiles

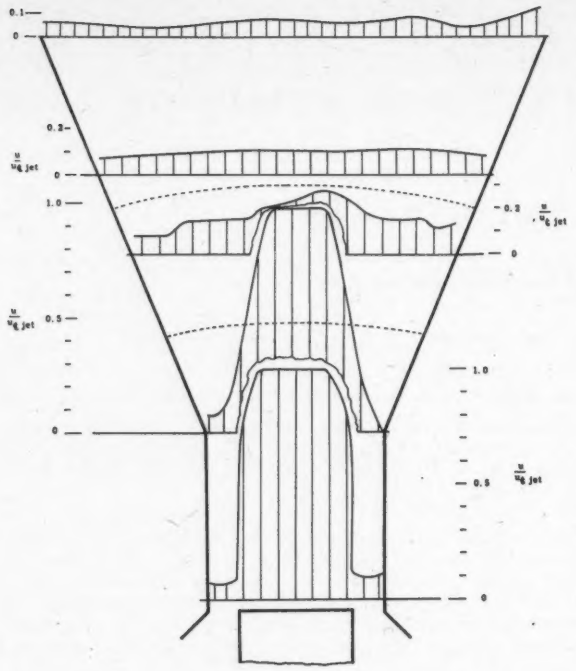


Figure 3
Velocity profiles

Altec-Lansing condenser microphone and a Muirhead Wave Analyzer were used for the acoustic measurements.

EXPERIMENTAL PROCEDURE

Aerodynamics

Initially an attempt was made to obtain a diffuser efficiency (defined as static pressure rise divided by kinetic energy drop) of 35%. Distributed rods and grids of rods that were expected to have enough resistance to prevent flow separation and result in this efficiency were tried in both models and the flow pattern was checked.

None of the rod distributions, even when quite dense (69% blockage at three stations) provided sufficient resistance to prevent flow separation in the diffuser. Finally screen combinations were tried until a satisfactory flow was obtained using two screens, one at area ratio two and the other at area ratio four in the symmetric model. Traverses were made on one diameter at four stations and on two diameters at the outlet (Figures 2 and 3). The pressure probes were kept parallel to the centre line after tests showed that no difference in reading could be measured while rotating the probe from parallel to the centre line to parallel to the flow. Static and total head measurements were made also along the centre line and one wall of the diffuser (Figure 4).

Acoustic

A reverberant room was used to compare the noise power output of the free jet with that of the muffler model (Figures 5 and 6). The room was not calibrated with the present equipment in place so that the values are comparative only and should not be taken as absolute

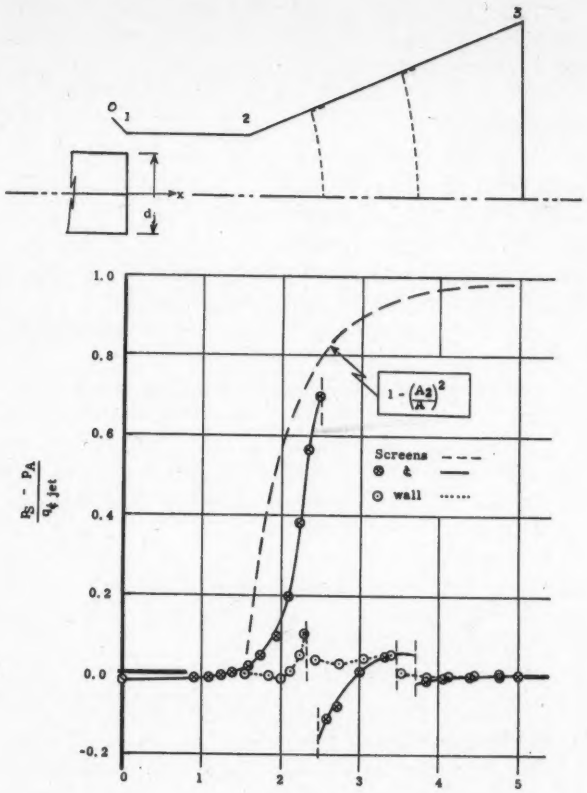


Figure 4
Static pressure along centre line and one wall

values. One-third octave band sound spectra were taken with the microphone in three different locations in the room. No differences were noticeable between results at the different locations, except at very low frequencies. Also measurements were made of the pressure level outside the boundary of the jet and along the outside of the diffuser. The acoustic equipment was calibrated before and after each run.

Resistance Coefficients — Rods and Screens

The tests which were made to determine the resistance coefficients of the screens and grids are reported in Reference 7. The method of Reference 8 was found to predict resistance coefficients accurately. However, it was noted that the calculated resistance coefficients must be based on the blockage of two separate grids if a space, in the direction of flow, exists between rows of rods making up a grid. For example, the grid which was tested was made up of two rows of 3/16 inch rods, one row horizontal and one vertical with a 3/32 inch gap between rows. Total blockage was 65%. The calculated resistance coefficient is if considered as one resistance 3.9, and if considered as two resistances 2.11. The test value was 2.05. This low value of resistance is no doubt the reason for the unsuccessful performance of the diffuser when rods were used.

RESULTS AND DISCUSSION

Aerodynamic

In Reference 7 a theory is developed for predicting the aerodynamic performance of the model. The induced flow (approx 13% of the jet flow) approached the theoretical prediction. Certainly the augmentor-diffuser worked well in reducing a high speed jet to a low speed movement of air, as indicated by the velocity profiles of Figure 3. Indeed the diffuser could be cut off at the area ratio four and still provide adequate theoretical noise reduction; at this station the flow has approximately 1/10 the speed of the free jet, providing a reduction of about 65 db according to the AV^8 law. It is interesting to note in Figure 4 that the slope of the centre-line pressure follows the theoretical slope reasonably well, and that there is a drop in pressure on the wall just inside the diffuser inlet. This is a good indication that the flow has separated from the wall at the sharp corner, as would be expected.

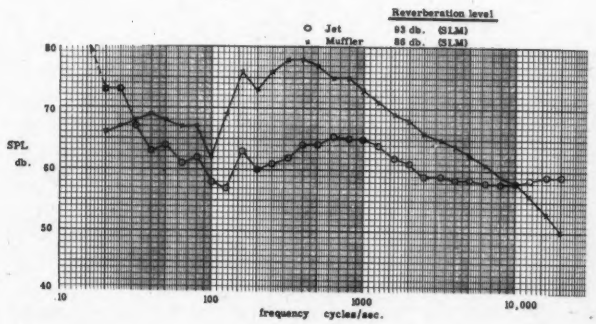


Figure 5
One-third octave pressure spectra for the jet and the muffler

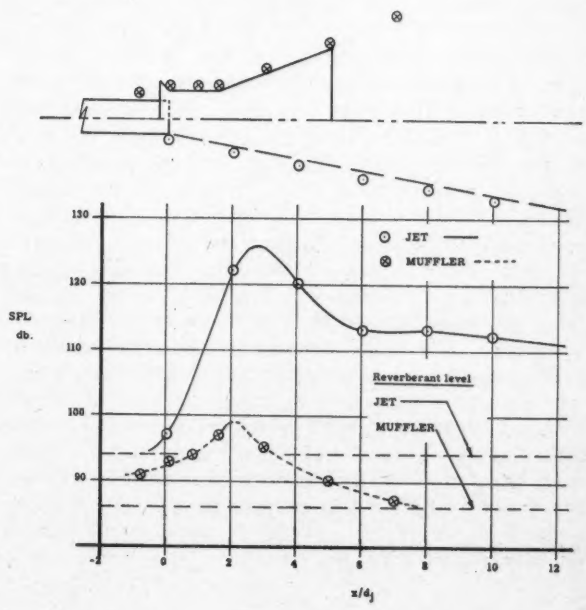


Figure 6
Pressure fluctuation levels along the edge of the jet and one side of the muffler

Acoustic

The model had been designed for an investigation of the aerodynamic performance of a wide angle diffuser in combination with an air augmentation system. There was virtually no acoustic treatment. When the aerodynamic performance appeared quite promising, it was decided to check the acoustic performance. Figure 5 shows comparative sound spectra of the jet with and without the muffler, taken with the microphone in one position in the reverberant room. It is obvious that from 20 to 20,000 cycles/sec the muffler produces a higher noise level than the free jet. Yet the measured overall sound pressure level of the muffler (86 db) is lower than that (93 db) for the free jet. It appears (see below) that the free jet must produce a very strong peak under 20 cycles/sec, below the range of the spectrum analyzer; this peak, which carries the bulk of the noise energy must be strongly attenuated when the muffler is fitted.

Evidence for the existence of such a sub-audible noise peak was obtained as follows:

The filters on the sound level meter were used to attenuate frequencies above 4,000 and below 800 cycles/sec. In effect, the energy below 160 cycles/sec and above 8,000 cycles/sec was cut out completely. Under these conditions, the sound level meter read 72 db for the jet and 81 db for the muffler. The noise level obtained by integrating across the spectrum, which resulted from adding the filter corrections to the original readings, compared within 1 db with the sound level meter readings. Thus the filtering out of noise below 20 cycles/sec, the lower limit of the spectrum analyzer, brings the results in line with the overall readings. The high end of the frequency spectrum is of such low energy level that it has little effect on the overall noise level.

A calculation was made in which the reverberation chamber with the door open was considered as a Helmholtz resonator. The calculated resonant frequency was 9.8 cycles/sec. It seems entirely possible that the inferred low-frequency peak was an excitation of this resonance, with or without essential modification by wall flexure or deflection around the door where the jet exhausted.

Figure 6 provides some information about the location of the main noise source since it indicates a maximum in pressure level in the region of the diffuser entrance. Inferences should be drawn with caution, however, since the near field pressure level is not a measure of noise power output per unit area. The aerodynamic indication of separation (see Figure 4) at the diffuser inlet, however, makes the point worthy of further investigation. The 25 db difference in peak pressure level in Figure 6 is also noteworthy and could indicate that with acoustic treatment a larger decrease could be obtained. The addition of a heavy outer wall would reflect some of the sound energy and result in more noise being absorbed by the acoustic liner. The addition of splitter plates or a constant diameter section, such as used in Reference 3, would be expected to further improve the acoustic performance.

When rods or grids were used in the diffuser a very high noise level resulted, probably due to Aeolian tones[9] or a similar mechanism.

CONCLUSIONS

(1) Wide angle diffusers which use resistance to prevent separation can be made to perform satisfactorily on a system with air augmentation.

(2) The large reduction in velocity which was achieved suggests that the configuration has potential for development into a successful jet muffler.

(3) The specific areas requiring further investigation are:

(a) the source of the noise within the muffler, particularly the flow separation at the diffuser inlet.

(b) methods of absorbing and attenuating the acoustic energy generated within the muffler, e.g. acoustically lined splitter plates or cylindrical extension; use of more massive muffler walls.

(c) problems related to cooling, i.e. increasing induced air flow by increasing length of mixing tube, the use of high-temperature screens, the use of grids of water-filled tubes instead of screens.

(d) effects associated with overchoked jets.

ACKNOWLEDGMENTS

The experiments described were carried out at the Institute of Aerophysics, University of Toronto, under the direction of Professor B. Etkin and with the joint financial support of Avro Aircraft Limited, Orenda Engines Limited and the Defence Research Board.

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TECHNICAL FORUM

Pioneer Aviators

THE uncertainty regarding the name of the first British subject to fly a powered aircraft has at last been clarified.

Our own F. W. (Casey) Baldwin, the first Canadian to pilot a powered heavier-than-air machine, believed himself to have been the first British subject to fly. This belief was probably based on the rather general impression that prevailed at the time of his flight, and since, that Henry Farman was a Frenchman.

Farman is reputed[1] to have made more than fifteen flights ranging from 100 to 300 metres over the parade ground at Issy les Moulineaux, France, on the 25th October, 1907. His first officially recognized flight was made on the 13th January, 1908, when he flew a closed circuit of 1 kilometre to win the Prix Deutsch-Archdeacon[2].

Farman was born in Paris on the 26th May, 1874, the son of a British subject who settled in Paris as the representative of a London newspaper. Henry Farman, now aged and ailing, has lived in France all his life, speaks French in preference to English, has thoroughly French sympathies and tastes and is said to have rather resented any suggestion that he was an Englishman.

He employed the French form Henri rather than Henry and indeed so marked his aeroplanes.

However, in The London Gazette, of the 17th September, 1909, this notice appeared:

"Whitehall, September 16, 1909 –

> The King has been pleased to give and grant unto Henry Farman Esq., His Majesty's Royal License and authority to accept and wear the Cross of Chevalier of the Legion of Honour conferred upon him by the President of the French Republic in recognition of valuable services rendered by him."[3]

In 1920 Farman was issued a British passport. He is reported to have become a naturalized Frenchman in 1937.

These significant facts establish beyond doubt that Farman, at the time of his first flights, was a British subject and hence the first British subject to fly a heavier-than-air aircraft.

The Gorell Committee, set up in 1928 by the Royal Aero Club of Great Britain, established[4] that Lt. Col. J. T. C. Moore-Brabazon made the first flight in a heavier-than-air aircraft by a British subject in the British Isles on the 2nd May, 1909.

S. F. Cody, a United States citizen at the time, made the first successful officially recorded sustained flight in an aeroplane in Britain on the 16th October, 1908. The date 16th May, 1908, on the plaque near Cody's tree at Farnborough has recently been found to be in error and is to be changed[5].

J. A. D. McCurdy made the first flight of a British subject in the British Empire in a powered aeroplane at Baddeck on the 23rd February, 1909.

Casey Baldwin was the first Canadian to fly a heavier-than-air machine on the 12th March, 1908, at Hammondsport, N.Y., and probably the seventh man to fly such a machine. His was also the first public flight in America. The flight was unique in that no preliminary ground runs or unsuccessful attempts were made and Casey did no practicing with the machine. The Red Wing was taken out on the ice, Casey climbed in and took off.

Casey retains the no mean distinction of being the first Canadian aviator; a distinction whose prestige will be enhanced as the years go by.

The achievements of Baldwin and McCurdy – intrepid pioneer Canadian aviators, the first to design and build aeroplanes in Canada, and with many other firsts which reflect credit on Canada and Canadian engineers – should be suitably recognized by a joint monument erected by Canadian technical societies at Baddeck in front of the Graham Bell Museum. If our roll is that of the sons of Martha, let us at least place on permanent record the work of some of the sons in that roll.

Ottawa — J. H. PARKIN

REFERENCES

(1) SCIENTIFIC AMERICAN, 2ND NOVEMBER, 1907, P 306.
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(4) FLIGHT, 21ST FEBRUARY, 1929, P 132.
(5) TIMES, LONDON, 17TH APRIL, 1958, P 6.

INSTRUCTIONS TO CONTRIBUTORS

The Canadian Aeronautical Institute invites the submission of papers, articles and technical notes for publication in the Canadian Aeronautical Journal. Following the practice of other societies, the Institute does not pay for contributions.

Authors should prepare their material in accordance with the following directions:

Manuscripts. Manuscripts should be
(a) Typewritten, double-spaced,
(b) On one side of 8½ x 11 white paper,
(c) With wide margins, approximately 1½", and
(d) With pages numbered consecutively.

Manuscripts must be in final form; the addition of material after acceptance by the Institute cannot be permitted.

Titles. The following form should invariably be adopted:—
(a) Titles should be brief;
(b) The name and initials of the author should be written as he prefers; (Rank or title preceding the name e.g. Wing Commander or Dr., should be included but abbreviations of degrees etc., after the name, should be omitted.);
(c) The name of the organization with which the author is associated should be shown under his name; and
(d) The author's position in the organization, referred to in (c) above, should be shown as a footnote to the first page.

Summaries. Each paper should be preceded by a summary
(a) Of 100 to 300 words, (10 to 35 lines, double-spaced),
(b) In non-specialist language, so far as possible,
(c) Stating the main conclusions of the paper.

Sub-Headings and Paragraph Numbering. Sub-headings should be inserted by the author at frequent intervals. Paragraphs should not be numbered.

References. References referred to by the author should be treated thus:—
(a) References should be numbered consecutively throughout the paper;
(b) An allusion to a reference should be indicated by a bracketed numeral e.g. "It has been shown by Dr. T. T. James (7) . . . ";
(c) Direct citation of a reference in the text should be written in full, e.g. "As shown in Reference (7) . . . "; and
(d) References should be grouped together in numerical order at the end of the paper, each showing
first, the numerical designation, e.g. "(7)".
second, the author's name, e.g. "James, T. T."
third, the title of his work, e.g. "Aerodynamics and Ballistics"
fourth, the title, volume, issue no, and date identifying the publication in which it appeared, e.g. "R.B.S. Journal, Vol. 7, No. 77, July 1907".

Thus "(7) James, T. T.,—Aerodynamics and Ballistics, R.B.S. Journal, Vol. 7, No. 77, July 1907."

Footnotes. Comments on or amplification of the text should be given in footnotes, appearing at the bottom of the appropriate pages.
(a) Footnotes should be designated alphabetically and consecutively throughout the paper; and
(b) A reference to a footnote in the text should be indicated by a bracketed letter, e.g. "omitting consideration of the third power (c) . . . "

Figures, Tables and Equations. Reference in the text to
(a) Figures and Tables should be given in full, e.g. "Figure 7", but
(b) Equations should be abbreviated to Eq., e.g., "Eq.(7)" or "Eqs.(5) and (6)".

Drawings. Drawings should be
(a) Individually identified by Figure or Table number,
(b) Not larger than 12" x 16",
(c) In black ink on white paper or tracing cloth, and
(d) Capable of being reduced to 3½" wide without loss of legibility of lettering or other detail.

Photographs. Photographs should be
(a) Black and white, glossy prints, and
(b) Individually identified by Figure number, written on a separate piece of paper affixed to the back: writing on the back of the photographs should be avoided.

Captions. Each Figure and Table should be identified by a caption, in addition to its number, e.g., "Figure 12 Theoretical lift distribution".
(a) The caption of a Table should be shown at the top of the Table;
(b) The caption of a Figure should be shown preferably outside the boundary of the Figure; and
(c) A complete list of Figure and Table captions should be given on a separate sheet of the manuscript.

Mathematical work. Only the simplest mathematical expressions should be typewritten; others should be carefully written in ink. Mathematical work should be
(a) Uncrowded—plenty of space should be provided to accommodate directions to the printer—,
(b) Repeated on a separate sheet of the manuscript, again uncrowded and with plenty of space around each expression,
(c) Clearly written to distinguish between like symbols. e.g. between zero and the letter 'o', and between Greek and English letters of similar form, and
(d) Accompanied by a manuscript "index" of the Greek letters used in the paper, identifying each letter by a name, e.g. "α—alpha".

In addition the following practices should be adopted:
(a) Simple fractions appearing in the text should be shown with a solidus, e.g. A/(B+C) rather than as

$$\frac{A}{B+C}$$

(b) Complicated expressions should be identified by some convenient symbol, if necessary to avoid repetition of the whole expression; and
(c) Complicated subscripts and exponents, and dots and bars over letters or symbols should be avoided.

Symbols and Abbreviations. Consistency is important;
(a) The symbols recommended in the American Standards Association "Letter Symbols for Aeronautical Sciences" ASA Y10-7—1954 should be used wherever practicable; and
(b) Abbreviations of units should be shown in lower case without periods, e.g. lb, mph, bhp, etc.

Mailing. Papers should be mailed to The Secretary, Canadian Aeronautical Institute, Commonwealth Building, 77 Metcalfe St., Ottawa 4, Canada.
(a) Drawings and photographs may be mailed rolled or flat, not folded;
(b) Manuscripts should be mailed flat.

C.A.I. LOG

SECRETARY'S LETTER

50th ANNIVERSARY GUEST

Last December I mentioned that the Institute was a member of an organization known as the National Coordinating Council for the Golden Anniversary of Flight in Canada. That organization has developed steadily since it was formed, setting up appropriate committees and promoting the formation of so-called Local Committees in various centres of aeronautical activity; each Local Committee is supposed to do locally what the National Coordinating Council is trying to do nationally, that is to coordinate any celebrations of its member organizations so that they will not conflict and, perhaps, to work out some combined operation suitable to this significant anniversary.

In this connection, I would urge the newly elected Executive Committees of all our Branches to recognize that they are heading into no ordinary year. They should do some planning now with a view to introducing some rather special events into their programmes, beginning in January 1959.

Anyway, what I was leading up to when I started, was to explain that, as the Institute's contribution to the work of the National Coordinating Council, we have offered office space to its manager, or Coordinator. W/C Harold Pearce was appointed to this post and took up his duties at the beginning of April. We are very glad to have him sitting in a corner of our Headquarters and, from the way things have been going, he will have plenty of coordinating to do.

HALIFAX-DARTMOUTH

The Chairman of the Halifax Local Committee on this Golden Anniversary business is CDR E. B. Morris, who is also Chairman of the CAI 50th Anniversary Committee. On the 16th April, I went to Halifax to see him and to attend the Annual General Meeting of the Halifax-Dartmouth Branch.

I spent the morning with CDR Morris and the Provincial Travel Bureau. When we were staging the Mid-season Meeting in Vancouver last February, we had a taste of Provincial enthusiasm, in that instance about the B.C. Centennial. It seems that next year we shall go through a similar experience, at the other side of the country, with our 50th Anniversary of Flight.

In the afternoon I attended a meeting of CDR Morris' Local Committee; and in the evening the Branch Annual General Meeting. Even at this Branch Meeting the Golden Anniversary pursued me; for there I met Mr. J. Hardman of Moncton, who is representing the CAI on the Moncton-Amherst Local Committee.

The Halifax-Dartmouth Branch, under the Chairmanship of Mr. E. C. Garrard, has nearly doubled its membership during the one year in which it has been in existence. A very good show, considering how long it took to get that Branch started. Which bears out my contention that, in almost every centre of aeronautical activity, the interest exists and requires only a little organization.

LIST OF MEMBERS

To enable us to give up to date details in the List of Members, which will be issued later on this summer, members are asked to complete and return as soon as possible the "buff cards" recently distributed to them. These cards provide an annual check on the particulars listed in Headquarters records and they are quite important to us. If a member does not return his card, we can include only his mailing address in the List, since this is the only information about him that we know with any certainty.

In this connection, I would remind my particular cronies that I do not make up this list personally; neither can I check it all. If they want to be listed properly they must treat us as an impersonal machine that has no memory and distrusts the current validity of last year's records. So, please, send in those cards.

ANNUAL GENERAL MEETING

Programme

May 26th Morning 9.00 a.m.

BUSINESS MEETING

President
G/C H. R. Foottit
Royal Canadian Air Force

Annual Reports of the Council and of the various Committees

May 26th Morning 10.45 a.m.

TEST PILOTS SECTION

Chairman
D. H. Rogers
Chief of Flight Operations, Avro Aircraft Ltd.

Annual General Meeting – Business Session

PROPULSION SECTION

Acting Chairman
D. E. Morrison
Chief Controls Development Engineer
Orenda Engines Ltd.

Annual General Meeting – Business Session

ENGINEERING ADMINISTRATION

Chairman
E. H. Higgins
Project Manager, CL-41, Canadair Ltd.

The Arrow Weapon System and Organization for Service Management

W/C D. W. Goss
Branch Head, Office of the Assistant to the Chief Aeronautical Engineer, RCAF HQ

Some Applications of Parkinson's Law

S. L. Britton
Chief Administrative Engineer, Orenda Engines Ltd.

May 26th Afternoon 2.30 p.m.

HONOURS AND AWARDS

Chairman
G/C H. R. Foottit
President, Canadian Aeronautical Institute

Honorary Fellows

McCurdy Award

F. W. (Casey) Baldwin Award

and

The W. Rupert Turnbull Lecture

Some Recent Aids to Aircraft Design

Dr. A. E. Russell
Director and Chief Engineer
Bristol Aircraft Ltd.

May 26th Evening 7.00 p.m.

DINNER

Chairman
G/C H. R. Foottit
President, Canadian Aeronautical Institute

Address

The Role of Science in Defence

A. H. Zimmerman
Chairman, Defence Research Board

May 27th Morning 9.00 a.m.

PRODUCTION ENGINEERING

Chairman

D. P. Stowell

Vice-President, Manufacturing, Canadair Ltd.

Tooling Approach to the Avro Arrow Aircraft

E. B. Bragg

Assistant Production Engineering Manager
Avro Aircraft Ltd.

Problems of Precision Production

F. W. Taggart

Chief Engineer, Aviation Electric Ltd.

Birth of an STOL Gear

L. Vadeboncoeur

General Manager, Jarry Hydraulics
Division of Jarry Automobile Ltée.

DESIGN AND APPLICATION OF COMPUTERS

Chairman

F. W. Prüden

Research Officer, National Research Council

Electronic Computers in Aviation Industry

G. S. Glinski

Canadian Regional Manager, ElectroData Division,
Burroughs Adding Machine of Canada Ltd.

Applications of a Large Scale Digital Computer in Aircraft Design and Development

A. O. Downing

Chief of Digital Computing, Avro Aircraft Ltd.

Computer Application to Fuel System Design and Development

J. M. Tusiewicz

Chief Performance Engineer, Lucas-Rotax Ltd.

The Application of Analogue Computers to Guided Missile Design

W. S. Kozak

Computer Engineer, Electronics Div., Air Armament Dept.
Canadian Westinghouse Company Ltd.

May 27th Afternoon 2.00 p.m.

GROUND EQUIPMENT

Chairman

G/C W. P. Gouin

Senior Logistics Coordinating Officer
Air Materiel Command Headquarters, RCAF

RCAF Emergency Runway Barrier Development

S/L W. M. McLeish

Officer Commanding Airworthiness Projects
RCAF Central Experimental and Proving Establishment

Weapon Systems Ground Support

J. F. Louv, Jr.

General Manager, Consolidated Diesel Electric
Corporation of Canada Ltd.

Aircraft Carrier Equipment

Capt. C. G. H. Daniel

Assistant Chief of Naval Technical Services (Air), RCN

VTOL/STOL

Chairman

J. L. Orr

Director of Engineering Research
Defence Research Board

Some Aerodynamic Characteristics of Wing-Mounted Lifting Fans for VTOL Applications

R. L. Wardlaw

Research Engineer

N. V. McEachern

Research Engineer

Division of Mechanical Engineering
National Research Council

VTOL Configuration Studies

E. B. Schaefer

Chief Engineer, Aircraft

K. Irbitis

Senior Engineer, Preliminary Design
Canadair Ltd.

Experimental Techniques in the Development of STOL Aircraft

Dr. G. W. Johnston

Aerodynamicist

Dr. D. H. Henshaw

Aerodynamicist

DeHavilland Aircraft of Canada Ltd.

MEETINGS

ANNUAL GENERAL MEETING

Notices giving the full programme of the Annual General Meeting have been sent to all members of the Institute; the programme is also set out on the preceding two pages.

ABSTRACTS

The following are abstracts of some of the papers to be presented at the Annual General Meeting.

The Arrow Weapon System and Organization for Service Management

W/C D. W. Goss – RCAF

In order to keep pace with advancing technology, it has become necessary to adopt the weapon system concept in the RCAF. Basically, this has placed the RCAF in the dual positions of customer and weapon system manager.

Simultaneous fulfilment of each of these roles is achieved through organization; compatibility of each with the other is assured through the establishment of realistic technical goals on the one hand and customer satisfaction by fulfilment on the other; and workability of the organization with the goals established and the limited RCAF manpower resources is achieved through the use of various 'tools' of organization.

With the foregoing as the basis of the general problem, the particular problems which have confronted the RCAF in its search for management for the Arrow Weapon System are presented along with their solutions.

Tooling Approach to the Avro Arrow Aircraft

E. B. Bragg – Avro

The paper outlines the basic approach in tooling the Avro Arrow aircraft from the original lines information supplied by the engineering division through the various phases of detail and assembly.

Brief mention is made of some of the major problems which occurred during the programme and some indications are made of the attempts to lower the tool build cost through the increased standardization of major jig frame members. The effect of this standardization on interchangeability is also mentioned and the interchangeability requirement, essential to the first Arrow aircraft, is also outlined.

Problems of Precision Production

F. W. Taggart – Aviation Electric

The paper presents a philosophic approach to a problem which, if we let it, becomes more and more difficult to solve. The technical problems which limit our abilities to produce are being rapidly lost in a maze of intricate mental barriers built by the product of today's specialization. The ability for the specialist to recognize the true problem is becoming increasingly difficult due to the trend and demand for ultra specialization.

Unanimity and mobility of mind and skills can help us to make full use of our Canadian industrial potential.

Birth of an STOL Gear

L. Vadeboncoeur – Jarry

The title of the paper is used in reference to the DHC-4 (Caribou) main and nose landing gear. The paper will cover the proposal and subsequent design, together with the production of prototype and qualification of an STOL gear. Tooling up and production will also be covered. In the production phase, major details being machined for the CL-28 Argus will be highlighted.

Electronic Computers in Aviation Industry

G. Glinski – ElectroData

The paths to successful finished products in aeronautical engineering usually require a large volume of routine computation. It is not surprising, therefore, that the aircraft industry was one of the first to avail itself of electronic computers to produce economically fast and accurate answers.

The purpose of this paper is to discuss several subjects, some of them controversial, in the field of automatic computing, such as the advantages of analog versus digital computation, evaluation of economic and time-saving features of computer use, selection of the size of computer installation and organization of computer facility.

Applications of a Large-scale Digital Computer for Aircraft Design and Development

A. O. Downing – Avro

The digital computer may be considered one of the most exciting developments of our generation. A large measure of credit for the present widespread use of digital computers must be given to the aircraft industry which very early applied them to its many problems and gave impetus to their development.

A digital computer facility has been available to the engineer at Avro Aircraft for several years. Recently, with the addition of an IBM Type 704 computer, the capacity of this facility was greatly increased.

This paper reviews a number of the major applications of computers in the aircraft design field and seeks to emphasize the essential nature of this equipment for the modern engineer.

Various aspects of the problem of utilizing a large scale computer with optimum efficiency are also presented.

Computer Application to Fuel System Design and Development

J. M. Tusiewicz – Lucas-Rotax

The problem of turbojet engine control is briefly outlined. Several possible approaches to control solution are discussed, then one version of the fuel system is described. Dynamics of the basic element of any hydraulic control system are examined. A few typical problems are discussed and applicable computer solutions are included.

In the second part, turbojet engine dynamics are studied both from the analytical and from the experimental point of view. Different levels of engine simulation are discussed. A more detailed description of an "economy" engine simulator is given.

A short examination of the significance of the computer contribution to fuel system design and development concludes the paper.

The Application of Analogue Computers to Guided Missile Design

W. S. Kozak – Can. Westinghouse

The analogue computer, on account of its inherent capability of providing continuous time-solutions to problems of dynamics, is a made-to-order device for the mechanization of complex dynamic systems. The guided missile, a prime example of advanced systems engineering, would not have reached its present stage of development without a

parallel sophistication of the analogue computer art. Many aspects of guided missile systems may be simulated, enabling both preliminary design and subsequent check-out of actual hardware. These aspects range from stability and trajectory studies to the inclusion of physical hardware into simulated loops. In this latter category, the analogue computer may provide signal inputs to missile amplifiers and servos, or through auxiliary apparatus operate missile control surfaces, or actuate an hydraulically operated flight table in a mock-up of flight conditions. Other aspects, such as the vindication of navigation laws, determination of stability and performance trends as a result of component tolerances, and the need for more sophistication in design or the redundancy of some components are readily ascertained through the judicious use of analogue computers.

RCAF Emergency Runway Barrier Development

S/L W. M. McLeish – RCAF

Recent jet fighter operational experience has focused attention on the runway overshoot problem. The nature of the problem and the solution, the emergency runway barrier, are considered in detail.

Reference is made to the USAF chain-type energy absorber which was evaluated by the RCAF as a possible solution. The CEPE analytical and experimental studies of the problem are reviewed and the inadequacy of chain-type arresting engine for heavy aircraft is proved.

The testing of an hydraulic arresting engine is described and an indication is given of the potential of this facility for arresting the CF-105.

A brief outline of the problems of the barrier engaging mechanism is included as well as some predictions of the configuration of the engaging method anticipated for the CF-105.

Finally, a few remarks are made concerning the feasibility of civilian applications of the barrier for commercial airliners.

Weapon Systems Ground Support

J. F. Louv, Jr. – Cons. Diesel Electric

The paper defines a weapons system as it applies to aircraft, missiles and ground support. The operation and maintenance concepts of ground support equipment are discussed covering types of equipment, power sources, mobility, manpower savings, cost savings and multi-purpose requirements.

An outline is given of the military approach as applied to the USAF and the RCAF with emphasis on the CF-105. This outline is followed by a discussion of the cross-utilization of ground support equipment in various Canadian systems.

Finally the author asks and answers the question "why an overall coordinator?", relating his answer to the phasing of support equipment in a programme, overdesign for the future and programme planning based upon horizontal rather than vertical authority.

Aircraft Carrier Equipment

Capt. C. G. H. Daniel – RCN

In the main, this paper will be concerned with the equipment fitted in an aircraft carrier which enables the operation of modern aircraft from a mobile landing strip less than 800 ft in length.

It will cover the angle deck, arresting and barrier gear, the steam catapult and the mirror landing sight.

Due to time limitations and security, technical and performance details will be limited to that necessary to give members an understanding of the operating principles involved.

Some Aerodynamic Characteristics of Wing-Mounted Lifting Fans for VTOL Applications

R. L. Wardlaw and
N. V. McEachern – NRC

Wind tunnel force measurements have been carried out on a wing-fan combination; the high-solidity fan was embedded in a two-dimensional symmetrical wing with the fan axis normal to the wing chord-plane.

Results are discussed and compared with a simple momentum theory, with a view to their usefulness in VTOL project studies. Over a limited range, fan power and model force measurements provide reasonable correlation with theoretical predictions.

An understanding of the flow in the vicinity of the fan is facilitated by surface pressure measurements and water tunnel flow visualization studies.

A method of applying the results to performance analyses is considered.

VTOL Configuration Studies

E. B. Schaefer and
K. Irbitis – Canadair

A comparative study was made of five VTOL aircraft configurations for an assumed transportation mission. Operational characteristics and economy were used as a basis for comparison. At the same time, an appreciation of the required research and development program was attempted.

The following configurations were investigated:

(1) Deflected propeller slipstream

(2) Tilting propellers and wing

(3) Tilting ducted propellers

(4) Jet life with turboprop propulsion

(5) Tilting jet engines for both lift and propulsion.

Within the limitations of the study, there was little difference in operating costs and it was concluded that the choice of a type for further detail investigation would, therefore, be based on operational characteristics and the required program of research and development.

APPOINTMENT NOTICES

The facilities of the Journal are offered free of charge to individual members of the Institute seeking new positions and to Sustaining Member companies wishing to give notice of positions vacant. Notices will be published for two consecutive months and will thereafter be discontinued, unless their reinstatement is specifically requested. A Box No., to which enquiries may be addressed (c/o The Secretary), will be assigned to each notice submitted by an individual.

The Institute reserves the right to decline any notice considered unsuitable for this service or temporarily to withhold publication if circumstances so demand.

Positions Required

Box 104 **Purchasing or Administration:** Purchasing man with 5 years experience in the aircraft accessories field requires position. Willing to relocate anywhere.

Positions Vacant

Technical Assistant: A vacancy exists for a Technical Assistant with a background of experience related to the overhaul of gas turbine fuel systems and accessories. Education to Engineering Standard or equivalent (Higher National Certificate). Applications should be made in writing only, giving complete outline of education, experience and salary required to Assistant Personnel Manager, Rolls-Royce of Canada, Ltd., Box 1400, Station O, Montreal 9, Que.

BRANCHES

NEWS

Edmonton

Reported by C. W. Arnold

March Meeting

The Edmonton Branch met on Wednesday, March 12th, in the RCAF Association Mess with forty members and guests attending the meeting. Mr. H. Stapleton, Vice-Chairman, presided.

A report on the proceedings of the Mid-season Meeting of the CAI, held in Vancouver, was given by Mr. J. A. Clarke.

Mr. J. G. Portlock then introduced the speaker, F/Sgt A. Rattray, who spoke on "The Limitations of Radar". This was a most interesting and concise talk, easily understandable to those who had no previous knowledge of the subject. F/Sgt Rattray's style was amusing and he handled the lively question period that followed very skilfully.

Mr. C. C. Young thanked the speaker and the meeting was then adjourned.

Montreal

Reported by F. M. Francis

February Meeting

The February meeting was postponed to March 5th due to the inability of the speaker to reach Montreal on the date scheduled. Mr. E. H. Higgins, Chairman, presided at the meeting which was held in the Airlines Cafeteria of the Aviation Bldg. There were approximately 75 members and guests for the dinner, including 15 students from Sir George Williams and McGill, with further members arriving after the dinner to swell the audience to over 100.

Mr. E. B. Schaefer, Chief Engineer, Aircraft, Canadair Ltd., introduced the speaker for the evening, Mr. W. W. Bender, Vice-President and Director, Rias, Inc. (Research Institute for Advanced Study – a wholly-owned subsidiary of the Martin Co. of Baltimore, Md.). The title of Mr. Bender's talk was "Space Age Basic Research".

Mr. Bender started his talk by pointing out that, although the recent expansion of technology has resulted in a considerable increase in the proportion of engineering talent which has been brought to bear, relatively few basically new concepts have been evolved since the end of the war. He attributed this state of affairs to the inability of the universities and other traditional research establishments, largely dependent on endowment or philanthropic patronage, to expand proportionally to the expanding industry.

To help to reduce the gap between basic research and engineering application, the Martin Co. had set up the RIAS in Baltimore and in this establishment some fifty research scientists are encouraged to pursue their own lines of endeavour. Mr. Bender gave a number of specific examples of the work which is now being done, giving a most encouraging picture of this attempt by industry to help itself in this neglected field.

March Meeting

Mr. E. H. Higgins was Chairman of the March 26th dinner meeting, held in the Airlines Cafeteria of the Aviation Bldg. Approximately 70 members were present for dinner and another 40 arrived to hear the panel discussion on VTOL aircraft, with Mr. J. L. Orr of the Defence Research Board as moderator.

Mr. J. T. Dyment, Trans-Canada Air Lines, W/C E. E. McCullough, RCAF, and Maj. J. L. Sloan, RCA, represented potential operators of VTOL machines. Mr. E. L. Smith, Canadian Pratt & Whitney, and Mr. K. Irbitis, Canadair Ltd., represented the manufacturers' side.

W/C McCullough started the discussion with a statement that RCAF requirements for a low speed VTOL machine were probably similar to those of the other operators, but added that so long as manned bombers exist manned fighters will also exist. Hence, it would be logical to consider the cost of extensive field facilities for conventional supersonic fighters against the penalties paid to achieve an equivalent VTOL airplane. Such a machine should be supersonic, have a 700 mile radius, hovering capability, suitable for all weather operations and require neither extra pilot skill nor unusual base equipment.

Maj. Sloan, speaking from the Army viewpoint, outlined how the ground forces could move "in the lap of the earth" given a VTOL machine which could overcome natural obstacles. The four major roles for an Army VTOL would be reconnaissance, logistics, assault and a flying crane. Maj. Sloan believes there will be a natural progression from the helicopter to STOL to VTOL. He defined an STOL airplane as one capable of clearing a 50 ft obstacle in 500 ft. He also pointed out that serious stability problems still remain to be solved for VTOL machines and offered the opinion that a combined STOL/VTOL airplane might be a reasonable compromise in that it would have a higher initial payload than the VTOL, yet land as a VTOL after fuel burnoff.

Mr. Dyment confined his remarks largely to helicopters as a means of solving the terminal to field problem and the short inter-city travel problem in highly populated areas, such as western Europe. He pointed out that, at the present time, although certain operators accept a lower standard of operational safety on helicopters than that provided in conventional airplanes, the majority of major airlines wish to see the breed developed to a far greater extent than at present. The current consensus of airline opinion is for a 40 passenger machine with a stage length of 200 nautical miles. The rate of climb with one engine out should be 150 ft per minute with all engine hovering capability at 5,000 ft. The helicopter should carry two pilots and, in addition, be equipped with an integrated automatic flight system. Mr. Dyment predicted that within 20 years supersonic trans-continental VTOL machines will be operating from downtown to downtown.

Mr. Irbitis, in presenting the airplane manufacturers' viewpoint, ran through the complete range of possible equipment from the helicopter to the supersonic VTOL machine. He described the advantages and disadvantages of each propulsion system and projected aerodynamic configuration in detail.

Mr. Smith, speaking for the engine manufacturers, stated that as the weight per pound of horsepower decreases through development of the gas turbine art, so does the day of really successful and versatile VTOL machines come closer. He offered the opinion that future development of VTOL aircraft might result in a much closer integration of powerplant and airframe design than heretofore and cited the shrouded propeller as an example.

Mr. Smith also mentioned that future development might also result in the elimination of the mechanical drive between the prime mover gas producer and the thrust producer.

MEMBERS

NEWS

E. K. Brownridge, F.C.A.I., formerly Vice-President, Manufacturing, has recently been appointed Executive Vice-President and General Manager of Orenda Engines Ltd.

Capt. C. G. H. Daniel, A.F.C.A.I., at present Assistant Chief of Naval Technical Services (Air), RCN HQ, will be taking up his duties as Command Technical Officer on the staff of the Flag Officer Pacific Coast at Esquimalt, B.C., on the 27th October.

I. A. Gray, A.F.C.A.I., formerly Director of Maintenance and Engineering, has been appointed Assistant Vice-President of Operations, Canadian Pacific Air Lines, Ltd.

J. M. Beauchamp, M.C.A.I., representative of Aerojet-General Corp. in north western U.S.A. and Canada for the past 10 years, has been named Director of Field Service for the company.

P. L. Bullock, M.C.A.I., has resigned his position with Canadair Ltd. to join Canadian Applied Research Ltd. as Manager, Aircraft and Group Sales.

R. J. Burden, M.C.A.I., formerly Asst. Chief Engineer, has been appointed Chief Engineer, Canadian Pacific Air Lines, Ltd.

R. W. Ellard, M.C.A.I., Field Service Representative for Avro Aircraft Ltd. was recently posted to Belgium.

J. Fleming, M.C.A.I., has been named President of the newly-formed Capital Air Surveys Ltd., Ottawa.

J. A. Gillies, M.C.A.I., formerly Chief Engineer, has been appointed Director of Maintenance and Engineering, Canadian Pacific Air Lines, Ltd.

R. L. Lake, M.C.A.I., has recently moved from Vancouver to Edmonton where he has taken up the duties of Supervisor of Maintenance, Pacific Western Airlines.

C. E. B. McConnachie, M.C.A.I., formerly with Canadian Pacific Air Lines, Ltd., has been appointed Manager, Sales Engineering, Canadair Ltd.

H. F. Young, M.C.A.I., formerly with Avro Aircraft Ltd., has been appointed Chief Production Engineer of Dosco's Steel Fabrication and Manufacturing Division, Montreal.

O. M. Cepella, Technical Member, has been appointed Manager of Service Engineering, Aeronautical Div., Honeywell Controls Ltd.

F. L. Trethewey, Associate, has recently retired from his position of Assistant to the President, Orenda Engines Ltd.

DEATH

It was with deep regret that we learned of the death of **C. S. Smith, Technical Member,** who was with Canadair Ltd.

ADMISSIONS

At a meeting of the Admissions Committee, held on the 3rd April, 1958, the following were admitted to the grades shown.

Associate Fellow

L. Kadlec, Manager, Staff Engineering, Avien, Inc., Woodside, N.Y.: *34-15 Seventy-Fourth St., Jackson Heights 72, N.Y.*

W/C T. J. Powell, RCAF, OC Flying Personnel Medical Establishment, Institute of Aviation Medicine, 1107 Avenue Rd., Toronto 12, Ont.

Member

F/L W. K. Bell, RCAF, AMTS/CAE/-AEng 2-4, AFHQ, Ottawa, Ont.: *594 Sparksdale, Ottawa, 2, Ont.*

P. J. Brunelle, Staff Officer Air Ordnance DAE, Directorate of Air Engineering, RCN HQ, Ottawa, Ont.: *917 Glasgow Cresc., Ottawa, Ont.*

FS R. R. Charron, RCAF, Draftsman Aero. Engr.–Superintendent, AMC HQ, Ottawa, Ont.: *1782 Haig Dr., Elmvale Acres, Ottawa, Ont.*

J. C. Howlett, Field Service Tech. Representative, Orenda Engines Ltd., Malton, Ont.: *116 Ravencrest Dr., Toronto 18, Ont.*

R. L. Jubinville, Engineering Technician, Elect. & Instrument, Canadian Pacific Air Lines, Ltd., Vancouver, B.C.: *4109 Grace Cresc., North Vancouver, B.C.*

S/L L. H. Keelan, RCAF, Tech. Services Officer AAED/CEPE, RCAF Stn. Cold Lake, MPO 503, Grande Centre, Alta.

A. R. G. Leckie, Head, Dept. of Aeronautics, Provincial Institute of Technology and Art, Calgary, Alta.

F/O A. Sjoberg, RCAF, Aircraft Servicing Officer, RCAF Stn. Winnipeg, Man.: *461 Conway St., Winnipeg 12, Man.*

Sgt. B. L. Taylor, RCAF (on transfer from Technical Member)

K. Tucker (on transfer from Technical Member)

W. A. Warwick, Sales, Carriere and MacFeeters, Scarborough, Ont.: *107 Rosemount Dr., Scarborough, Ont.*

H. L. Williams, Instructor, Service Dept., Transport Div., Boeing Airplane Co., Seattle, Wash.: *c/o H. L. Hunt, 1637 Harwood St., Vancouver 5, B.C.*

Technical Member

R. J. Bishop, Product Engineer, Aircraft Division, Thompson Products Ltd., Louth St., St. Catharines, Ont.

P. L. Cowan, Field Engineer, Computing Devices of Canada Ltd., Ottawa, Ont.: *516 Driveway, Ottawa, Ont.*

S. R. Fletcher, Design Draftsman, Avro Aircraft Ltd., Malton, Ont.: *25 - 43rd St., Apt. 2, Long Branch, Toronto 14, Ont.*

W. R. Foote, Junior Engineer, Avro Aircraft Ltd., Malton, Ont.: *2 Poynter Dr., Toronto 15, Ont.*

S. C. MacKinnon, Material Planner, Northwest Industries Ltd., Edmonton, Alta.: *10313 - 124 St., Edmonton, Alta.*

R. L. Warnica (on transfer from Student)

Junior Member

E. G. Stonier, Air Traffic Controller, Dept. of Transport, Vancouver, B.C.: *4208 West 15th, Vancouver 8, B.C.*

Student

Y. J. H. Alloucherie, University of Toronto, Toronto, Ont.: *1402 Parc Champoux, Quebec 6, P.Q.*

S. D. Benner, University of Toronto, Toronto, Ont.: *Sunset Dr., R.R. No. 1, Fort Erie, Ont.*

J. K. Dukowicz, University of Toronto, Toronto, Ont.: *183 Grenadier Rd., Toronto 3, Ont.*

F/C T. J. Grinnell, Canadian Services College, Royal Roads, Victoria, B.C.

F/C D. K. Hamakawa, Canadian Services College, Royal Roads, Victoria, B.C.

F/C G. W. Hosang, Royal Military College, Kingston, Ont.: *25 Bonnington Pl., Willowdale, Ont.*

Z. Miezitis, University of Toronto, Toronto, Ont.: *227 Indian Grove, Toronto 9, Ont.*

F/C W. C. Moore, Canadian Services College, Royal Roads, Victoria, B.C.

F/C R. W. Morton, Canadian Services College, Royal Roads, Victoria, B.C.

F/C S. H. Newroth, Canadian Services College, Royal Roads, Victoria, B.C.

G. Pappas, Provincial Institute of Technology and Art, Calgary, Alta.: *608 Crescent Rd., Calgary, Alta.*

F/C K. J. Parkes, Canadian Services College, Royal Roads, Victoria, B.C.

F/C A. W. Pchajek, Canadian Services College, Royal Roads, Victoria, B.C.

R. E. Smith, University of Toronto, Toronto, Ont.: *134 Lawton Blvd., Toronto, Ont.*

Cadet R. L. Sykes, Canadian Services College, Royal Roads, Victoria, B.C.

SUSTAINING MEMBERS

NEWS

Computing Devices of Canada Ltd. during the last six months, has signed exclusive sales agreements for Canada with five foreign firms. These new agreements complement existing arrangements with Benson-Lehner Corp. and the Computer and Pacific Divisions of Bendix Aviation Corp. Benson-Lehner make equipment for reducing film or chart records to digital quantities. Bendix Pacific manufacture a digital telemetering system known as Electrospan and Bendix Computer manufacture the Bendix G-15D digital computer.

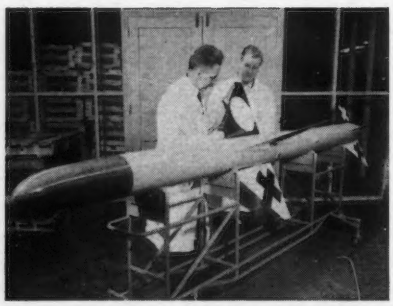
The new agency agreements are with Epsco Inc., Traid Corp., Flight Research Inc., Reeves Instrument Corp. and O.M.I. Corp. of America.

Epsco Inc. manufacture a line of very high speed analog to digital and digital to analog converters, capable of speeds up to 45,000 conversions per second with an accuracy of 0.05%, as well as digital telemetering equipment.

Reeves Instrument Corp. are best known for REAC analog computers. CDC operates a 96 amplifier REAC in their Computing Centre in Ottawa, in addition to two digital computers.

Photographic instrumentation manufactured by Flight Research Inc. and Traid Corp. will enable CDC to fill all requirements for special purpose military and industrial cameras. Flight Research specialize in multiple synchronous cameras in 16, 35 and 70 mm, for accurate data acquisition in aircraft and missile testing. Traid Corp. build photographic instrumentation systems, including high speed (up to 200 frames per second) scoring cameras, gun cameras and interval data recording cameras.

Most recent of new CDC agencies are Ottico Meccanica Italiana, of Rome, Italy, and the O.M.I. Corp. of America, suppliers of what is claimed to be the widest assortment of photogrammetric instruments made by a single manufacturer. High quality photomappers, photostereographs and stereocomparators are the most important instruments in the line.



The Sparrow 2

Canadair Ltd. has announced that it is going into immediate production on the Sparrow 2, the first Canadian-built operational air-to-air guided missile. The Sparrow is produced under license agreement negotiated between the Canadian Government and the Douglas Aircraft Company Inc., with the concurrence of the U.S. Navy.

Under the terms of its contract, Canadair is appointed coordinating contractor and as such has the overall responsibility for the manufacture, assembly and flight testing of the missile. For the past seven years, Canadair has been engaged in programs in Canada for the development of air-to-air guided missiles.

Canadian Westinghouse has been appointed an associate contractor to produce the radar seeking system. Firms who will do sub-contract work for Canadair on the program are Aviation Electric Ltd. and De Havilland Aircraft of Canada Ltd.

Canadian Pacific Air Lines, Ltd. took delivery of its first Britannia 314 on the 11th April. This same aircraft made a proving flight from Filton to Vancouver in February, in connection with the opening of CPAL's new hangar, subsequently returning to England. The delivery flight was made in 16 hr 35 min with one stop, at Calgary, for re-fuelling.

The Britannia will be introduced on the Vancouver to Amsterdam route on the 1st June. Later Britannias will be working on routes from Vancouver to Tokyo and Hong Kong; to Honolulu, Fiji, Auckland and Sydney; and to Mexico City, Lima, Santiago and Buenos Aires.

METAL AND WELDING SHOW

Members of the CAI have been invited to attend a Metal and Welding Show which is being staged by Alloy Metals Sales Ltd. on the 21st, 22nd and 23rd May. The Show has been arranged to mark the completion of their new warehouse and office extension at 181 Fleet Street East, Toronto. It will be open from 3.00 to 9.00 pm on the 21st and 22nd May and from 1.00 pm to 6.00 pm on the 23rd May.

Twenty-two Canadian and American companies will be exhibiting and their technical men will be on hand to answer design, production and fabrication problems.

There will be five welding clinics, where the latest equipment for welding and brazing Inco Nickel Alloys, Stainless Steel, Aluminum and Magnesium will be demonstrated.

In addition, the latest technical and non-technical films on related subjects will be shown continuously.

ATMOSPHERE AND HIGH ALTITUDE CHARTS

The Garrett Corporation has produced two very interesting charts, one referring to the atmosphere up to 100,000 ft altitude and the other, known as the High Altitude Chart, going up to 2,000,000 ft. The charts are coloured and present standard values of the temperature, pressure and specific weight of air and are illustrated to show man's achievement from kites to satellites. The Company has very kindly agreed to supply these charts, on request, to members of the Institute. Application should be made to

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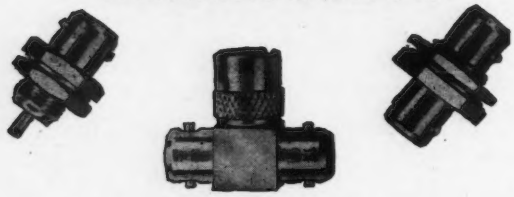

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Back Numbers

A demand exists for copies of the Canadian Aeronautical Journal, Volume 2, Nos. 1 and 3, issued respectively in January and March, 1956.

Readers having copies of these issues for sale are requested to notify The Secretary, Canadian Aeronautical Institute, 77 Metcalfe St., Ottawa 4, Ont.

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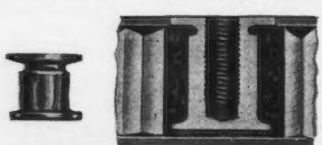

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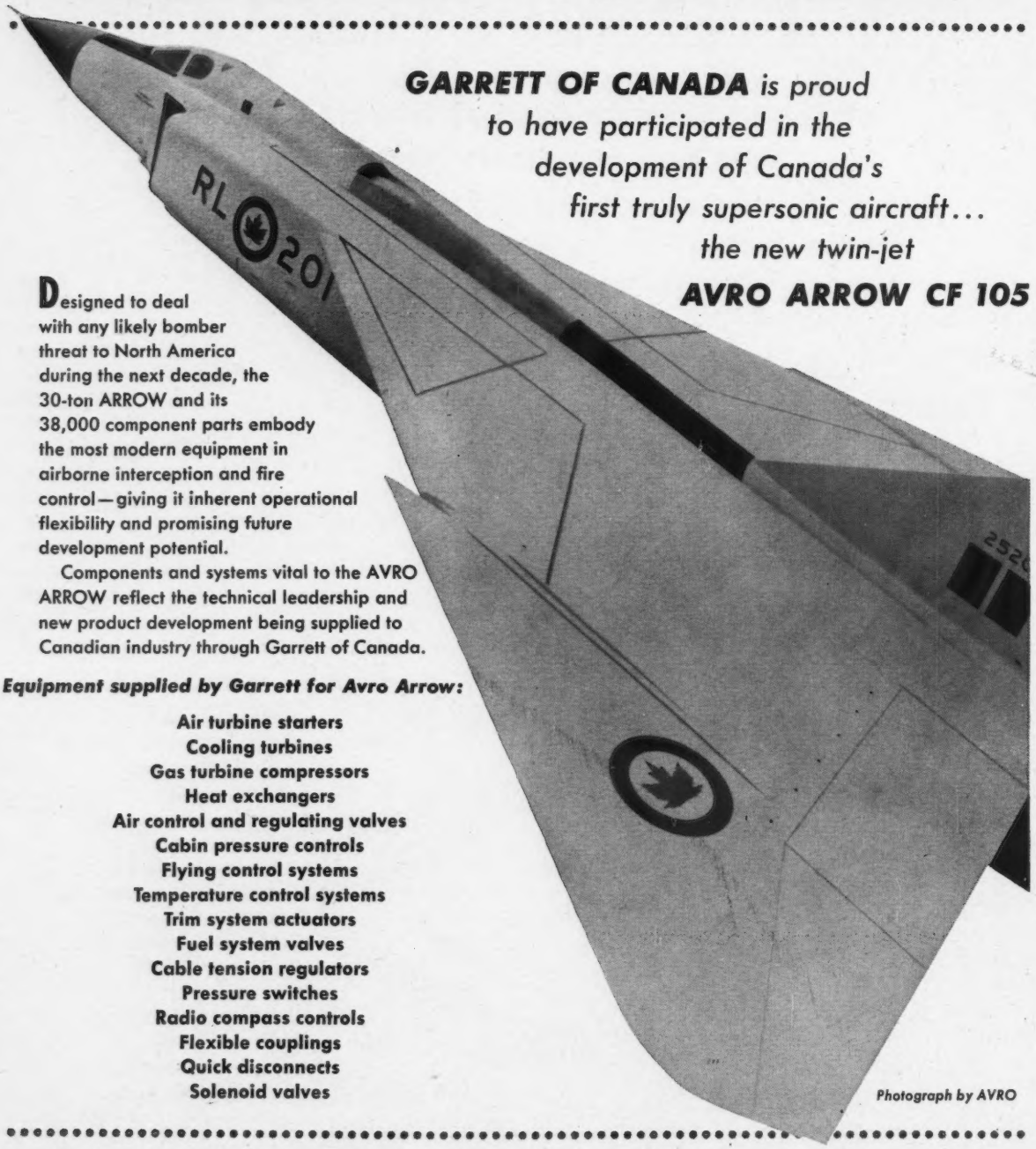

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ILLUSTRATED BROCHURE

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MEMBERSHIP OF THE C.A.I.

THE qualifications and annual dues set out in the table below are those presently laid down by the By-laws. The rates of dues shown in brackets are those applicable to members resident outside Canada or the U.S.A.

The annual dues include a non-deductible subscription to the *Canadian Aeronautical Journal.*

Applications for membership must be made on the approved forms, which may be procured from the Secretaries of the Branches or from C.A.I. Headquarters. An applicant does not apply for membership in any particular grade, but each application is considered by the Admissions Committee, who decide the grade suitable to the applicant's qualifications. On admission, the applicant is informed of his grading and the appropriate entrance fees and annual dues.

The entrance fee is $5.00, except in certain special circumstances.

Grade	Summary of Qualifications	Annual Dues
Student	Undergoing a course of study at an approved school of engineering or technology	$3.00 ($2.00)
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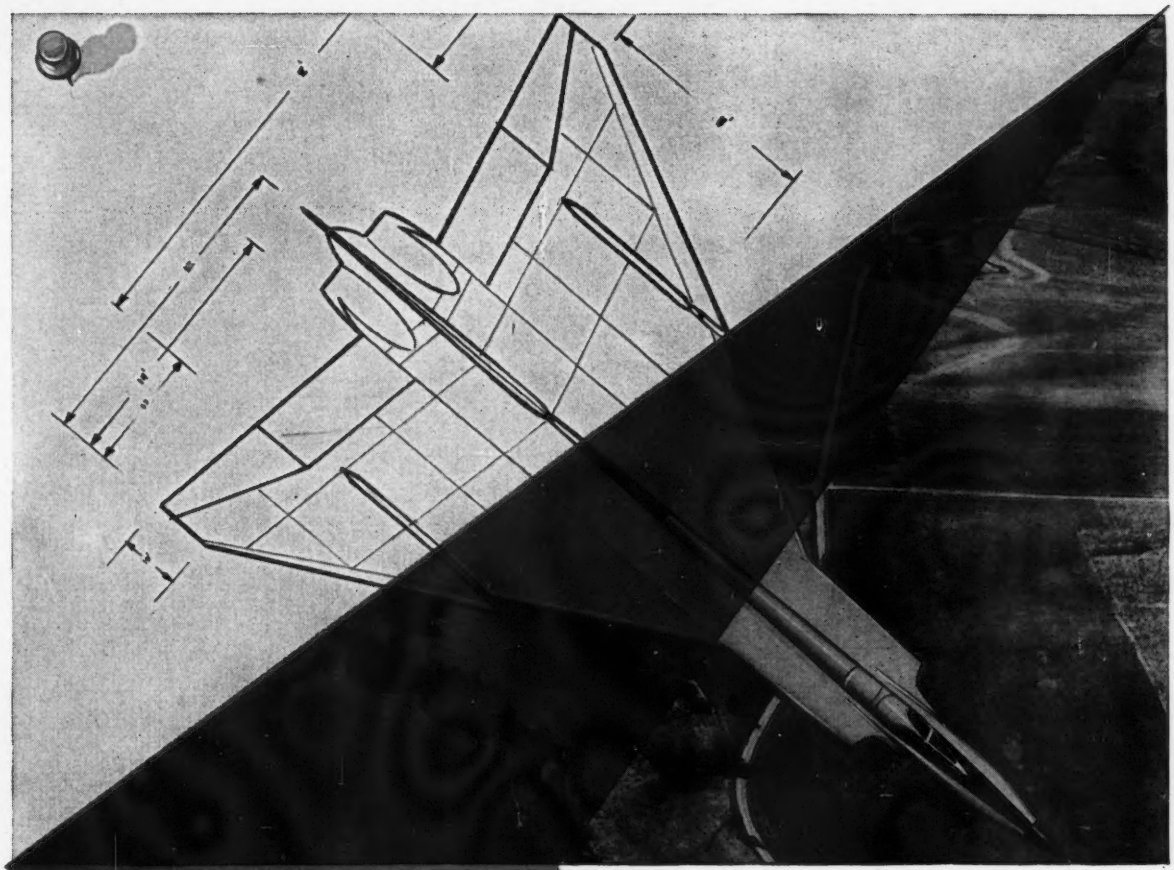

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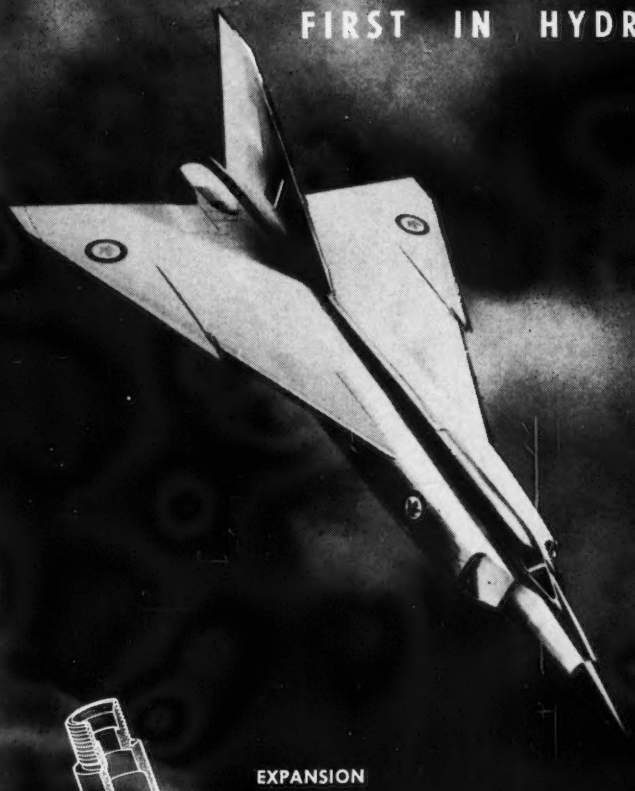

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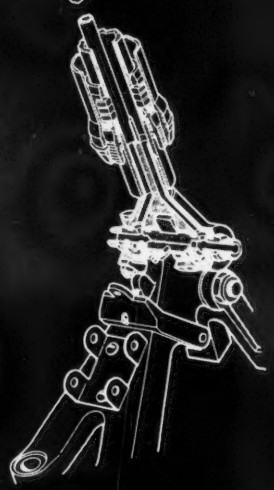

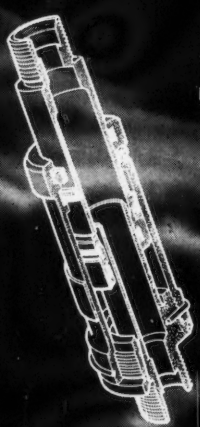

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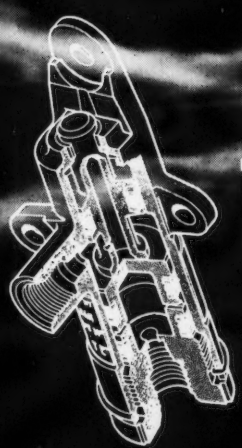

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EDITORIAL

ELECTRONICS IN AVIATION

THERE is no doubt in the mind of any engineer in the aeronautical field that electronics is an essential part of the aircraft industry. What is not generally realized is the magnitude of the part played by electronics, and the problems that face the Canadian electronics industry if it is to keep pace with the Canadian development and production of airframes and engines which have created such noteworthy aircraft as the Arrow and the Argus.

On the average, the electronic equipment in the modern military aircraft amounts to almost 50% of the cost of the entire aircraft. When to this is added the cost of the ground radar, the test equipment, simulators and the electronic devices associated with the manufacture and servicing of the aircraft, it is safe to say that over 50% of the funds expended in the aircraft industry today are expended on electronic development and equipment. This is substantiated by the United States defence budget expenditures. When compared with the 10% figure of World War II and the fact that the content in guided missiles is even higher, the vital importance of electronics to the aircraft industry becomes obvious.

Because of the difficulty in defining "electronics" as such, the term "avionics" has been coined to cover electronics in aircraft and, in general, represents all the electrical, electro-mechanical and servo devices in which tubes, transistors or other electron control devices are essential components.

It is obvious from an examination of the world's economy that the countries which rely principally upon supply of raw materials to others are the poor members of our world society. This is becoming more and more manifest as finished products increase in complexity with an ever rising content of more expensive labour. Most economists agree that a high standard of living depends upon industrialization. Canada, for instance, could not have enjoyed the prosperity experienced since the war if it were not for the industry created during and after the war. In few other major industries is the ratio of manhours to raw materials so high as in aircraft manufacture and Canada owes a great deal to those courageous individuals, in government, armed services and commercial circles, who, after World War II, had the vision and initiative to promote and support an aircraft industry in this country.

The ratio of manhours to raw materials in avionics is higher than in most other aspects of the aircraft industry. It is unfortunate therefore that, in Canada, development of the avionics industry has not kept pace with aircraft development, primarily because of the difficulty of competing with manufacturers in the U.S.A., who already have built up powerful teams and resources with U.S. government support. A very obvious and logical conclusion is that Canadians, to help retain the present standard of living, must exert all possible effort toward building up a strong avionics industry. It is also very obvious that, because of the basic defence requirements and large sums of money involved, the industry cannot do this from its own resources, but must rely upon a well integrated, long term government supported plan.

It is encouraging to see the efforts now being made to promote Canadian avionics production in such devices as the Sparrow missile, the fire control system for the Arrow, navigational systems and flight simulators, but it is regrettable that an aircraft industry which is capable of producing one of the world's most advanced aircraft has had to rely upon sources outside Canada for the major portion of the avionics development. Let us hope that the same courage and foresight which inspired the growth of the aircraft industry will now be applied to promoting the corresponding development of what is a vital aspect of the industry – avionics.

J. M. BRIDGMAN
Vice-President and Gen. Manager
Canadian Applied Research Limited

HYDROSTATIC FUSELAGE PRESSURE FATIGUE TEST PROGRAM LOCKHEED C-130A HERCULES†

by D. S. Morcock*

Lockheed Aircraft Corporation, Georgia Division

SUMMARY

Tests of a structurally complete C-130A fuselage are being conducted to evaluate the fatiguing effects of combined internal pressure and flight loads encountered by a C-130A in normal service. This article describes the set-up and test procedure, and the results of over 10,000 simulated flights.

The test is being run outdoors by the Engineering Research Laboratory on a specially constructed slab, with the assistance of the Engineering Experimental Division.

INTRODUCTION

A USAF contract was awarded in 1955 to the Georgia Division, Lockheed Aircraft Corp., for pressure fatigue testing of a C-130A fuselage. In an earlier program, another C-130A was statically tested to 15 psi internal pressure and to a combination of 11.25 psi internal pressure and design ultimate flight loads. The static test program, utilizing air and (later) water as the pressurizing medium, was completed before the pressure fatigue test was begun.

TEST PROGRAM

The purpose of the pressure fatigue test is to reproduce the fatigue damage on the fuselage which would be caused by many flights of a C-130A airplane, each flight involving internal pressure and flight loads. On the basis of Miner's cumulative damage theory and of the expected usage of the C-130, a test requirement of 25,000 cycles consisting of a single application of 1.72 g vertical down load in conjunction with 7.5 psi internal pressure was defined, each cycle simulating one 3 hr flight to altitude.

TEST SPECIMEN

The test article consisted of a structurally complete (but otherwise bare) C-130A fuselage, including the center wing section. The vertical fin and a stub horizontal stabilizer were added to complete the pressure vessel and to provide a means of applying the tail load. Figures 1, 2 and 3 show the configuration of the test article.

LOAD SYSTEM

The load system was designed to apply the shear and the bending moment due to a 1.72 g vertical down load factor, based on a gross weight of 96,000 lb, acting on the fuselage. This was accomplished indirectly by loading the wings upward until the desired loads were produced as reactions in the fuselage, which was moored to the base of the test site. The two jacks loading each wing were positioned to apply the proper wing shear, moment and torque to the wing-fuselage junction. A jack at the aft end of the airplane pulled down to simulate the flight load on the horizontal tail.

Figure 1
A structurally complete C-130A fuselage was manufactured for the pressure fatigue test

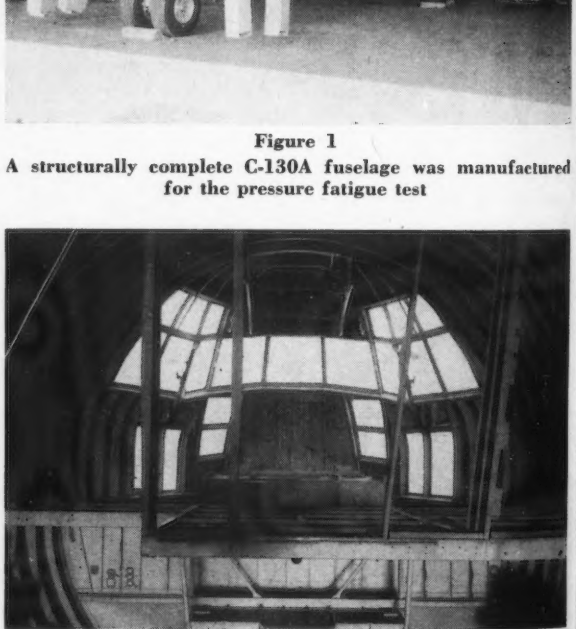

Figure 2
All non-structural equipment was omitted from the pressure fatigue test article

Sponge rubber padded load beams in the treadway area of the cargo floor, 20 inches wide and 8 to 12 ft long, and twenty-two aluminum load straps bonded to the fuselage sides forward and aft of the cargo area were linked together by two whiffletree systems, one connecting all forward loaders and straps together and the

†Received 25th April, 1958.
*Aircraft Research Engineer.

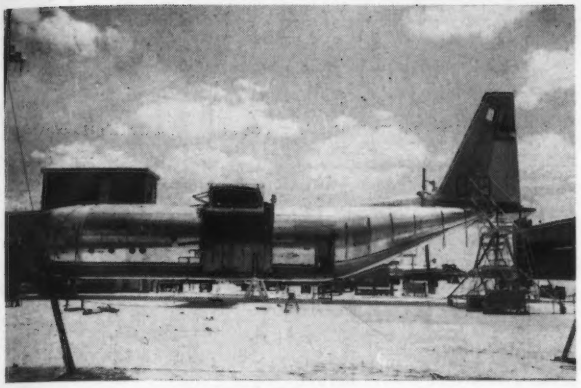

Figure 3

Dummy landing gears were utilized to support the airplane; the test tank was then constructed around the fuselage

other connecting all loaders and straps aft of the wing. Each of the two systems was anchored to the floor. Figures 3 and 4 show the load beams and straps. Baldwin electrical load cells were used to monitor the load produced at the two reaction points. The geometry of the whiffletrees produced the desired distribution of load to the loading straps and the internal loading beams.

(Preliminary tests conducted to determine the feasibility of bonding loading straps to the side of the fuselage indicated that some creep of the bonding material could be expected. Strips of 0.051 aluminum 2 inches wide were bonded together over a 13 inch length with Proseal 380M sealant. Transverse ⅛ × ¼ inch aluminum strips were spaced at 3 inch intervals along the bonded area to produce a uniform bond thickness of ⅛ inch. Vacuum blankets were used to hold the specimens together until the bond set. These strips proved satisfactory in static tests and fatigue tests for a shearing stress of 40 psi. Creep tests at 20 psi stress of similarly fabricated straps, following immersion in water for varying lengths of time, indicated that the material would creep under load to a deflection of 1 inch in about twenty days before failing. On the basis of the laboratory tests, the pressure fatigue test straps were designed for a maximum operating stress of 20 psi. The 2 inch wide straps were bonded to the fuselage over a length of 45 inches, using transverse spacers of ⅛ inch thick material, ¼ inch wide, spaced throughout the bonded region. Vacuum blankets were used to hold the strips against the side of the fuselage while the bond was setting. An allowable creep of ½ inch was established, after which the bond was to be renewed. However, in practice, the creep has been less than 1/16 inch in 10,000 cycles and no replacement has been necessary.)

Figure 4

Sponge rubber faced loading beams were linked to external load straps to apply 1.72 g flight loads to the fuselage

All jacks were calibrated prior to installation in the fatigue test jigs. Calibrated Baldwin pressure transducers were installed in the hydraulic pressure lines at the base of each jack. Hydraulic pressure was provided by a 100 hp Denison heavy duty industrial power supply. The output from this unit was directed through pressure regulator valves and flow control valves to the jacks.

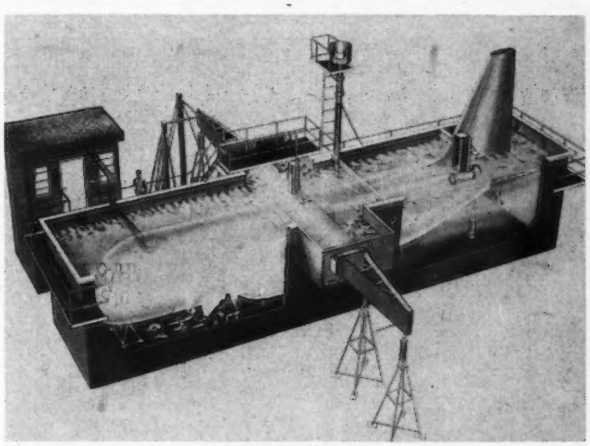

Figure 5

Sketch of test set-up showing control tower, tank, dummy outer wings, loading jacks, strain gage cables, and water standpipes and dump valve

PRESSURIZATION SYSTEM

Water was used for pressurization for two basic reasons:

(1) Damage which might be incurred in a blowout would be minimized by the use of an incompressible fluid, as compared with the damage which would be sustained if air were the pressurizing medium.

(2) The use of water for pressurization effected a more rapid cycling rate than could be realized using air, since the movement of a relatively small volume of water was sufficient to pressurize the fuselage.

The airplane was filled with water and surrounded by water to eliminate the differential pressures due to water head. A tank 20 ft high, 20 ft wide and 100 ft long was built around the fuselage for the test. Figure 5 is a sketch of the test arrangement. The tank was composed of 8 ft long sections of ⅜ inch thick steel plate reinforced on 32 inch centers by 10 inch H-beams. The segments of the tank were bolted together. The tank walls were seated on 1 inch thick closed cell sponge rubber 12 inches wide. The two sides of the tank were connected by ¾ by 4 inch steel straps at approximately 32 inch intervals at the bottom and 96 inch intervals at the top. Diagonal straps tied the ends to the sides. Thus the water pressure acting on one side of the tank was

reacted by the pressure on the opposite side and no side loads were transferred into the concrete slab. Studs imbedded in the slab were used to tighten the walls down onto the sponge rubber for sealing. The cutout for the wing was filled by a seal of rubberized fabric bonded to an aluminum plate closing the end of the wing center section. Figure 6 shows the seal. The completed test set-up is shown in Figure 7.

Water pressure was provided by a 15 hp water pump with an output of 700 gal/min at 100 psi. The water was directed through a shut-off valve to 4 inch diameter pipes entering the fuselage through a fitting installed in the right paratroop door. As the water pressure was built up inside the airplane, water was backed up in the standpipe until it reached the top, where it actuated a float switch causing the water valve to close and three dump valves to open, exhausting the excessive

Figure 6

A dummy outer wing panel was bolted to the center wing through a plate sealed to the tank by rubberized fabric

water back into the tank and thus reducing the internal pressure. A pressure manometer, pressure gage and a pressure recorder were used to monitor the applied pressure. Because of the time required to actuate the valves, the float switch was adjusted to operate when a pressure of 7.4 psi had been attained. Overflow from the standpipe at 7.5 psi occurred on all normal cycles.

The tank, which contained 270,000 gals of water, was filled from a fire hydrant, using four water hoses. Two hours and thirty-five minutes were required for filling. Chromic acid was added to the water as the tank was being filled to provide a neutral pH factor. Figure 8 is a wide-angle view of the submerged airplane.

AUTOMATIC CONTROLS

An automatic control system, based on electrical relays and timers, was devised for the test. The panel operated electrically controlled solenoid valves which directed the hydraulic pressure to the jacks and water to and from the fuselage. In addition to the automatic control system, switches were provided on the panel to permit manual operation of individual components. Two control panels were fabricated so that if one panel should become inoperative during a run, the other panel could be pressed into service without delay. The panel is shown in Figures 9 and 10.

Figure 7

A concrete slab containing load pads and tie-downs was constructed as a base for the test jigs, shown here in an overall view

SAFETY DEVICES AND MISCELLANEOUS EQUIPMENT

A number of safety devices were installed to insure proper operation of the test. Switches wired to indicator lights showed the position of the fuselage ramp door, which was closed and locked after the tank was filled. Mercury switches mounted on levers were used to control the roll of the airplane. A roll of about 0°30′ would cause the solenoid valve for the outboard wing jack on the high wing to close, permitting the other wing to continue to rise until the roll was eliminated. If excessive roll occurred despite this precaution, an additional mercury switch was set to automatically stop the cycle. A similar provision was made to halt the test if excessive pitch should occur.

Figure 8

The airplane fuselage and center section were completely submerged and filled with water. Additional water was pumped into the fuselage for pressurization

Lights on the control panel were wired to microswitches attached to the water valves. These lights indicated the position of the valves at any time. In addition, the microswitches energized timers which would initiate audible and visual warnings if excessive time were required to pressurize the airplane.

A telephone and a public address system were installed. The control room was air conditioned and steam heated to provide a controlled temperature for the strain gage equipment. The control panel, safety devices and communications were housed in the control room at water level. Hydraulic and water pumps, plumbing and valving were installed on the ground floor of the control room.

STRAIN GAGES, FAILURE WIRES AND TELEVISION

Approximately thirty rosette and axial gages were applied to the airplane to provide a check of the stresses at specific locations. An elaborate waterproofing procedure was used on the gages, but results were unsatisfactory due to the use of cables which were not waterproof, as advertised, but were merely water resistant. Nevertheless, strain data were obtained for load only, pressure only, and combined load and pressure conditions.

Failure wires were utilized for a time during the test program as a check on crack propagation. Monitoring of the wires was discontinued when it was found that the cracks did not extend beyond their initially discovered length. A closed circuit television camera, viewing through a pane set into the side of the tank, was also used for a time to monitor the growth of a series of cracks in a rivet pattern.

PRELIMINARY CHECKOUT

A preliminary checkout of the loading system and pressurization system was made while the tank was being constructed. The automatic control panels were tested by 10,000 cycles of operation utilizing a dummy checkout board. Hydraulic accumulators were placed in the lines of the completed hydraulic system to allow movement of the oil under pressure and the electrical control panel was used to apply a simulation of 3,000 automatic cycles to the hydraulic loading system. In later operation it was found that both the hydraulic system and the automatic control panel were very reliable. It is felt that the preliminary checkout was a contributing factor to this reliability.

Following completion of the loading system, the flow rates and the maximum pressures applied to the hydraulic jacks were regulated during manually operated tests. Load and pressure transducers at the jacks and at the reaction points were monitored during these checkouts. The pressure system was also checked out manually before automatic cycling was begun.

TEST PROCEDURE

Automatic cycling was begun on September 6, 1956. Through January 1958 over 13,000 cycles had been applied. A typical test run was conducted as follows.

The tank was filled with the fuselage ramp door open. When the tank was filled, the water input from the fire hydrant was reduced to an amount which would barely overrun an overflow slot cut into the side of the tank. The ramp was closed and locked hydraulically; then automatic cycling was initiated. The test was run on a two shift basis. Following the application of 300 simulated flights, the ramp was opened and the tank was drained for airplane inspection. A typical simulated flight required about one minute twenty seconds. Hydraulic pressure was directed to the jacks and immediately thereafter the water valves were operated to pressurize the airplane. Full load was reached in about fifteen seconds; approximately sixty seconds were required for pressurization. When the pressure reached 7.4 psi, the switch in the standpipe was closed, initiating the closing of the water valve, the opening of the dump valves, and the opening of the solenoid valves to remove the hydraulic pressure from the jacks. The cycle was automatically logged on a counter when the pressure was released.

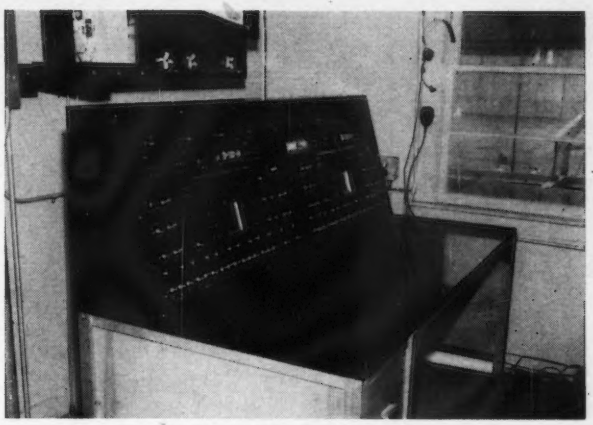

Figure 9
Two automatic cycling control panels were fabricated to expedite testing. Switches permitted manual control

For the initial phase of the program, skin divers were sent into the tank at intervals of 50 to 150 cycles to check the progress of known cracks. (When divers were used the chromic acid was omitted during filling. The test was shut down while the divers were in the tank.) It was found, however, that propagation of the cracks was generally negligible and the divers were therefore discontinued after about 3,000 cycles had been applied.

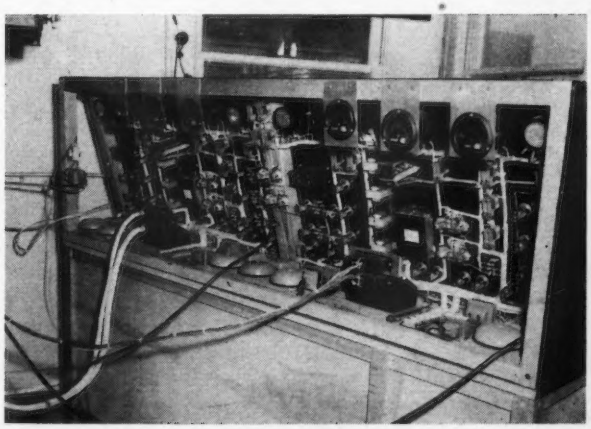

Figure 10
Relays and timers were basic elements of the control panel, shown here in a rear view

Following each draining of the tank, a shake-down inspection was performed. During the early phase of the program, this inspection was performed by all available personnel until a failure was found; then the inspection was continued by a Quality Control inspector while repairs were underway. After 10,000 cycles, eight mechanics were used to perform the entire shakedown. All repairs were inspected by Quality Control before testing was resumed.

FAILURES

Failures which were found were referred to the C-130 Structures Group for disposition. Prior to the completion of 10,000 cycles, consideration was given to the application of the repair to production airplanes and, in many cases, a proposed modification was incorporated for evaluation. Above 10,000 cycles, the basic attempt was made to restore the airplane as a pressure vessel by a convenient means and proposed modifications were then incorporated when convenient. Some failures were left without repairs to evaluate their effect on the surrounding structure.

Several types of failures were encountered. Cracks in the skin were found in general to propagate for a length of not over 1 inch and then to cease propagating. In only a few cases did cracks extend to a greater length and then the cracks could not be seen until the entire area had failed. Miscellaneous small bolts and screws failed in particular areas with consistent regularity. These were replaced for a time and were then increased in size when it was obvious that they were failing repeatedly. All such areas were watched carefully since the broken attachment could be indicative of overloading of the surrounding structure.

Miscellaneous attachment fittings were relatively trouble-free until after 10,000 cycles, with the exception of the fittings connecting the floor to the wing support beams, the aft cargo door hinges and the forward cargo door hooks. A number of major blowouts occurred. (A major blowout was defined as a failure in which extensive damage was incurred and partial or complete loss of pressure resulted.) Only once was there any warning that the failure was impending.

Fatigue scatter between similar parts was found to be quite low during this test. A maximum fatigue scatter of the order of 2.5 was encountered.

Failures and repairs were reported in monthly progress reports to the USAF. In addition, a log of failed parts was kept. After 6,000 cycles, an interim report detailing the test procedure, failures and repairs was issued. At the close of the program the additional failures which have been encountered will be added to this report. The reporting of repairs was enhanced by the use of photographs and sketches.

CONCLUSIONS

The following general conclusions were reached.

(1) The use of water for fatigue testing of pressure vessels is practical and convenient and provides a rapid means of testing.

(2) The number of failures which can be expected during a program of this type necessitates the incorporation of access doors and power stands into the basic test set-up.

(3) A properly designed automatic control system based on timers and relays will furnish very reliable operation.

(4) Fatigue results cannot be fully evaluated by the use of laboratory tests of components only. The fatigue scatter in the case of the Hercules was greater in the laboratory component tests than in the fuselage test and, in general, the fatigue life which was exhibited by a part tested in the laboratory was much greater than the life of the same part incorporated on the airplane. A partial explanation of this phenomenon is that the distribution of load cannot be fully predicted.

(5) Fatigue scatter of similar parts on the airplane was very low, of the order of 2.5 maximum.

(6) Thorough inspection to discover failed parts before secondary damage was created by the failure was found to be most worthwhile. However, despite close inspections, almost all major failures occurred without advance warning, i.e. the progression to failure was such that it could not be detected visually. This emphasizes the need for pressure fatigue tests of all high altitude transport type aircraft to discover areas of weakness that cannot safely be found by other means.

The following conclusions were reached regarding the C-130 airplane.

(1) The first major failure was encountered at 3,200 cycles (9,600 hrs). This is considerably beyond the 1,000 hr modification program in which the first changes resulting from findings of the fatigue test program will be incorporated into service airplanes.

(2) The overall fatigue life of the airplane has been substantially increased as a result of the fatigue test program. It is presently felt that a fatigue life of 30,000 hrs can be expected when the necessary modifications have been incorporated.

(3) Laboratory tests and fuselage fatigue tests of similar parts showed considerable disagreement in fatigue life, with laboratory tests generally indicating a life three to eight times the life indicated by the pressure test. (This observation is based on a relatively small number of parts.)

(4) Much damage can be sustained by the pressure vessel without resulting in a blowout. On the other hand, the airplane in its original configuration had several weak points which could not be detected prior to a major failure. These weak points have now been eliminated.

(5) No provision was made in the fatigue test for simulation of propeller blast or vibration. Failures due to vibration are being found in service airplanes. Also, the accuracy of Miner's theory in using a single load to simulate the fatigue effects of all the miscellaneous loads encountered in flight is open to question. However, failures appear to have resulted mainly from the pressure loads and it is felt that the number of cycles sustained before a failure occurs might be affected by a different load spectrum but that the important result, determining weak points in the pressure vessel, has been achieved.

ASTRONAUTICS—SCIENCE OF SPACE EXPLORATION; AN INTRODUCTION AND SUMMARY OF PROGRESS†

by G. D. Watson*

Defence Research Board

SATELLITE LAUNCHINGS INFLUENCE ATTITUDE TO ASTRONAUTICS

THE successful launching of the first Sputnik has introduced a new scientific era and changed the point of view of the whole world. The turn of the year between 1957 and 1958 corresponds to the time when the first explorers of North America were returning with furs and other evidence that there were new lands to explore. Their exploits proved that the world was round, or at least that it was not flat with a bottomless pit surrounding the edges. The launching of five additional satellites since the 4th of October has convinced the skeptics and given new stimulus to the space science enthusiasts.

The moon, the planets and the stars have always been visible to man and, throughout the ages, thoughts, talk and writings about space travel have existed soon after man developed the capability for each of these skills. The word Astronautics, which implies travel to the stars, has been in existence for some time as title to the science of space travel, but it has been used with lack of confidence until recently. The first practical steps in the exploration of space have been made and scientific experiments can now be used to supplement the theoretical background which is already well advanced.

ROCKET PROPULSION NECESSARY FOR EXPLORATION OF SPACE

Most of the general theoretical science necessary for exploration of space has been understood for some time but practical space vehicles have not been possible because of limitations in the performance and size of rocket motors. The recent development of large rocket motors has made it possible to place earth satellites in orbit and further development will eventually lead to practical space vehicles.

Some of the earliest speculators did not realize that rocket propulsion was necessary for space travel and suggested the possibility of sailing to the moon in ships or flying there on wings. However, these early ideas were soon replaced by recognition that reaction devices of the rocket type are the only powerful propulsion engines that can develop the thrust necessary to blast vehicles into space and continue to operate in the space vacuum. The rocket, essentially as we know it today, was discovered by the Chinese about 1200 AD — nearly 800 years ago — and has been used as a weapon or as fireworks ever since. The early military rocket was not particularly successful because it could not be designed with sufficient accuracy and, although it was used as a barrage weapon by the Chinese and the Indians, it was not until after 1800 that Congreve of the United Kingdom developed a rocket which had any modern military significance. Even then, improvements in artillery, resulting from the introduction of rifling, again put the rocket into eclipse until World War II when it was developed in a number of forms culminating in the V-2 which, with a range of 200 miles, was considered to be a very long range ballistic missile.

Other approaches to rocket development were also important; Tsiolkovski, the earliest Russian space travel writer, wrote a paper in 1895 in which space travel using the multiple stage rocket was discussed. The paper is the foundation of Russian work in the field. During the first World War, the American scientist Robert Goddard investigated the possibility of using rockets for the exploration of very high altitudes and his paper, entitled *A Method of Reaching Extreme Altitudes*, opened the modern era of rocket development. A few years later, Herman Oberth, Professor of Mathematics working in Germany, published a paper entitled *The Rocket in Planetary Space* and expanded it a few years later in *The Way to Space Travel*, reference book of all space enthusiasts. After World War I the German Rocket Society was formed and worked with enthusiasm to attain space travel until the work was interrupted by World War II. Although the basic objectives were delayed, the large scale financial and manpower support which is given to wartime enterprises no doubt advanced the basic rocket techniques required for exploration of space more rapidly than would have been possible in peacetime. In recent times the British Interplanetary Society and the American Rocket Society have been active in maintaining interest in the field. Following Tsiolkovski's paper in 1895, Russian writers started publishing papers on the subject and recent translations indicate extensive activity in the last few years. With the new acceptability of space science, the amount of published material is increasing rapidly.

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The rocket is based on the simple basic law of physics, now famous as Newton's third law of motion, which states that for every action there is an equal and opposite reaction. Basically, a rocket consists of a tube, containing some fuel, which is closed at one end and opened through a nozzle at the other. When the fuel or propellant is burned the gases are projected from the nozzle at high velocity, creating a reaction force or thrust to drive the rocket forward.

Rocket fuels may be either solid or liquid. In the former, the fuel and oxidizer are solid and mixed together, usually being cast or extruded into a hollow stick which quite often is bonded by a cement to the outside tube. In this way, the inside of the propellant is free to burn while the outside is prevented from burning because of its bonding to the case. This design protects the rocket case from the high temperature gases which would otherwise heat it to such a temperature that it would be weakened and burst under the pressure generated by burning.

Although solid fuel rockets are simple and reliable, the fuels and oxidizers which have suitable characteristics do not give as high performance as can be obtained from liquids; consequently, many of the larger rockets have used liquid fuels and oxidizers. Liquid oxygen, one of the best oxidizers, is used with many different fuels including liquid hydrogen. The V-2 used liquid oxygen and alcohol. Other rockets use liquid oxygen and kerosene. Nitric acid is sometimes used as the oxidizer, with kerosene or aniline as the fuel. Table 1 gives performance characteristics for a number of typical fuel-oxidizer combinations, along with theoretical non-chemical possibilities.

The higher specific impulse and the greater ease of control of thrust levels have made it necessary to use liquid fuel rockets for satellite launchings and, if advanced rocket motors do not become available in time, they will be used for moon rockets and space travel also.

TABLE 1

TYPICAL THEORETICAL SPECIFIC IMPULSE FOR ROCKET FUELS

Rocket Type	Spec. Impulse Seconds	Remarks
Chemical:		
Oxygen-Alcohol	220	
Oxygen-Kerosene	260	
Oxygen-Gasoline	260	
Red Fuming Nitric Acid-UDMH	275	
Oxygen-Diborane	310	
Oxygen-Hydrogen	360	
Fluorine-Hydrogen	370	
Free Radical:		
H+H radical H_2 diluted	775[6]	Chamber temp. 3000°K
H+H radical	2160[6]	Very high temp.
Chemo-Nuclear:		
Nuclear-H_2	600-800[1]	Chamber temp. 4000°F
Nuclear-H_2-H radical	3000[1]	
Accelerated particle:		
Electrically accelerated N+ions	millions	Electrical field used to accelerate ions gives high velocity without excessive temperature. Weight of nuclear to electrical energy conversion machinery prohibitive with present techniques.
Fusion-Magnetohydrodynamic	millions	Extremely high temperatures (millions of degrees). Chamber protected by pinch effect.

RESEARCH REQUIRED TO IMPROVE ROCKETS

The great interest in space research has stimulated intensive examination of new methods for creating rocket thrust. The chemical fuel systems are reaching the limit of their capability and, although some improvement is possible, it is unlikely that specific impulse can be raised more than a few per cent. The theoretical specific impulse of 360 for liquid hydrogen-liquid oxygen rocket would represent an improvement of only about 50% over that attainable with liquid oxygen and alcohol.

Nuclear reactions offer the best possibility of getting high energy per unit weight of fuel and several different nuclear-powered rocket types are under study. The combination nuclear-chemical engines in which a nuclear reactor is used to heat a working fluid, like liquid hydrogen, may be the first practical engines with major improvement in performance.

If the weight of nuclear reactors can be reduced sufficiently, it will be possible to get specific impulses of the order of 600 to 800 sec[1] and thrusts of thousands of pounds with a relatively low chamber temperature of about 4,000°F. If improvements in reactor and chamber materials are developed to the point where much higher temperatures could be used, it has been indicated[1] that specific impulses of the order of 3,000 sec might be possible with dissociated hydrogen as the working fluid.

The controlled fusion reaction might also be used to heat liquid hydrogen, but a practical fusion reactor is probably farther away than the fission reactor which is already operative for fixed powerplant use. The gain in specific impulse would be similar to that obtained for the fission reactor rocket.

Solar heat has also been proposed[2] as a possibility for creating the temperature required to accelerate hydrogen. A large parabolic reflector would be used to direct solar radiation onto the chamber of the rocket for space ships operating outside the atmosphere. This motor, which would provide relatively low thrust for correction and manoeuvre in the coasting phase of space flight, may provide a satisfactory solution for limited power derived from the environment on relatively long flights.

All of the combined heat source-working fluid engines are limited by the velocity with which the gas molecules can be ejected at temperatures which can be contained in the rocket. This limitation has led to examination of the possibility of accelerating nuclear particles, ions or photons and using the reaction of these particles for thrust. Since the atomic particles or molecular fragments could be accelerated to a high proportion of the speed of light, they would be ejected at velocities several orders of magnitude above those attained by molecules from chemical fuel rockets. It has been suggested[1] that, if it were possible to control the direction of flow of fission or fusion fragments themselves – for

example, if magnetic fields could be used to direct the exhaust of the high temperature particles of plasma or fully ionized gas from the fusion reactor – a theoretical impulse of millions of seconds is possible. This new hope for powerful space engines is being explored under the new science of electrohydrodynamics[3], which may eventually develop a whole new technology allowing design of practical high thrust engines.

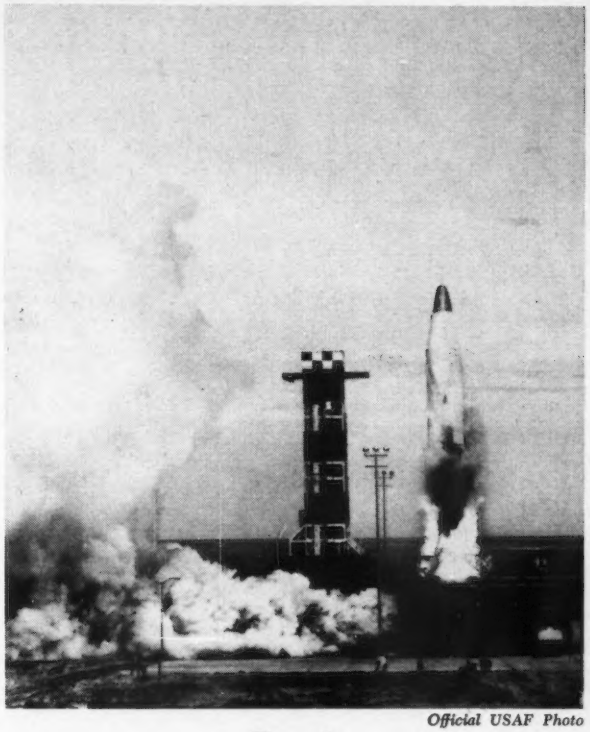
Of the accelerated particle engines, the ion rocket has been the subject of recent research and Stehling[4] expresses the opinion that the ion rocket is likely to be the first practical powerplant using charged particles. Even so, his computations don't encourage a practical engineer to undertake a contract to build one in the immediate future. He describes an ion rocket in which a nuclear reactor will be used to produce positive ions from nitrogen and, at the same time, drive a gas turbine electrical generator to accelerate positive ions to high velocity and discard electrons to maintain electrical balance. He computes that a small 10 ton space ship would call for a propulsive power of 1,500 Kw at 750 v and 2,000 amp. At 25% overall power efficiency, this would require a 6,000 Kw power source which, he points out, would weigh more than 10 tons with present day rotating machinery for converting nuclear to electrical energy. Both Stehling[4] and Bussard[5] point out that before particle rockets will be practicable a more direct conversion from nuclear to electrical energy is needed.

Free radical chemistry is being studied, also, as a possible road to new high specific impulse engines. These unstable molecular fragments have a high energy of dissociation and if methods, such as cryogenic cooling or anticatalysts, can be developed to stabilize them and allow controlled release in a rocket chamber they could provide important improvements. For example[6, 7], the reaction H + H into H_2 gives a limiting specific impulse of 2,160 sec. If present day restrictions on motor temperature to about 3,000°K were observed, the H radicals would have to be diluted by H_2 and 1.7 moles of H_2 plus 1 mole of H radicals would give a specific impulse of 975 sec or nearly three times that of today's rockets.

Propulsion is the limiting factor in space experiments and it seems that this condition will continue for some time yet. In the meantime, brute force methods utilizing chemical rockets will undoubtedly continue to expand the space horizon until new techniques are practicable.

BALLISTIC ROCKETS — MAJOR STEP TOWARD SPACE VEHICLES

The German V-2 was the forerunner of modern long range rockets. The liquid fuel rocket motors, developed by scientists of the Rocket Society to satisfy their enthusiastic hopes that some day they might send a rocket to the moon or a satellite around the earth, formed a basis for development of the V-2 with a capability of approximately 200 miles maximum range. Further developments of the same rocket in the United States and Russia have increased the range to infinity, that is to the point where the rocket can place satellites in orbit with extremely long periods of life. There are many ballistic rockets in existence or in development. The Army Jupiter and Air Force Atlas, Figure 1, and Thor, Figure 2, are typical of modern ballistic rockets. Jupiter



Official USAF Photo

Figure 1

USAF Atlas intercontinental ballistic missile

Official USAF Photo

Figure 2

USAF Thor intermediate range ballistic missile

and Thor have a range of about 1,500 miles and the Atlas intercontinental ballistic missile has a range of more than 5,000 miles. Most ballistic rockets are single-stage, that is they have a single stage of tankage and motor which is separated from the payload after the fuel is burned. The large ballistic rocket motors provide the thrust necessary to place relatively small vehicles in orbit. Similar motors with increased thrust will be required for larger space vehicles.

BALLISTIC TRAJECTORIES AND SATELLITE ORBITS

Kepler, one of the early astronomers and, incidentally, one of the earliest authors on the subject of space travel, discovered the laws of motion for objects operating under the influence of gravity. The most fundamental law states that a planet travelling about the sun describes an ellipse with the center of the sun occupying one focus of the ellipse. Although Kepler's laws were stated as applying to planets travelling around the sun, they apply equally to any body travelling under gravity in an orbit relative to another. In the case of the ballistic rocket, the trajectory is an ellipse with one focus at the centre of the earth but, because of insufficient velocity, the ellipse intercepts the surface of the earth and only a short segment of a complete orbit is possible. As the range of a rocket is increased, the ellipse is expanded and the rocket can be used to launch a satellite travelling around the earth in a complete orbit. The orbit may be nearly circular or it may have considerable eccentricity, that is, the ellipse may have its perogee quite near the surface of the earth and its apogee at a considerable distance. In any event, ballistic rockets, satellites and eventually space ships are all governed by Kepler's law. This simple law applies as long as the two bodies are sufficiently isolated from other objects – a condition which fortunately applies for most space orbits of immediate interest. Although the computation of space orbits is not as simple as Kepler's law would indicate, it is expected that satisfactory accuracy will be attainable using existing methods[8], even when third body and other complications are introduced.

EARTH SATELLITES

Although the laws governing the motion of orbiting objects are relatively simple, the job of establishing an earth satellite is difficult for several reasons. Of greatest importance is the fact that the earth is relatively large and the force of gravity demands the expenditure of a considerable amount of energy to lift the satellite; furthermore, although the earth's atmosphere is life sustaining, it demands that any satellite of reasonable length of life must be launched at an altitude of about 200 miles. Thus, the establishing of earth satellite orbits has had to wait for the development of rocket engines with sufficient power to give the satellite a velocity of about 18,000 miles/hr or 5 miles/sec, at 200 to 400 miles altitude.

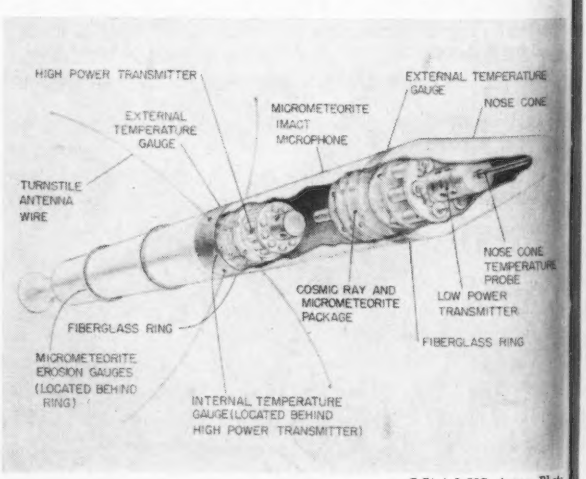
It is in connection with satellite launching that multiple stage rocket technique becomes particularly important. To attain the very high velocities and lift the satellite 200 or more miles above the earth requires a large amount of fuel which must be contained in tanks. Without undertaking a detailed analysis, it is obviously wasteful to use fuel to accelerate

Official US Army Photo

Figure 3

Launching of the Jupiter-C (Explorer) from Cape Canaveral, 10.48 pm EST, 31st January, 1958

these tanks to higher and higher velocity after they are empty. The multiple stage rocket is a technique by which fuel tanks and unwanted structure can be discarded when they are no longer needed. In this way the second stage rocket, starting with the velocity given to it by the first stage, can accelerate a small mass to higher velocity than would be possible if the first stage tanks had not been discarded. The Soviet satellites are believed to use three stages and the US Explorer, Figure 3, used four. In the case of Sputnik II and the Explorer, the



Official US Army Photo

Figure 4

Explorer scientific earth satellite

final stage, which is a solid fuel rocket, remains attached to the instrumented compartment and forms part of the satellite. This has a number of advantages besides the obvious one that no separating mechanism is required. In particular, since the final stage rocket has the same velocity as the instrument package, it will stay in orbit anyway and leaving it attached enhances both the visibility of the satellite and its radar reflective area, and avoids the confusion between the satellite and the rocket which might arise in observations if the components were separated. Sputnik I did separate the final stage rocket, the satellite itself and a nose cone, and, at times, all three of these objects were observable. Sputnik II and the Explorer, Figure 4, have the final stage rocket and nose cone attached, but Vanguard, Figures 5 and 6, like Sputnik I, is designed to separate from the final stage rocket, leaving a spherical satellite body which gives more meaningful drag data and makes low level satellite orbits easier to predict.

The satellites already launched are a part of the International Geophysical Year, a cooperative program to get more scientific information about the earth. They all carry scientific instruments and transmitters to relay the information to the ground. Although the first satellite transmitters did not last very long (presumably because they used chemical batteries with relatively short life), solar batteries that derive their energy from the sun appear to be successful and later satellite transmitters have been operating continuously since their launching dates.

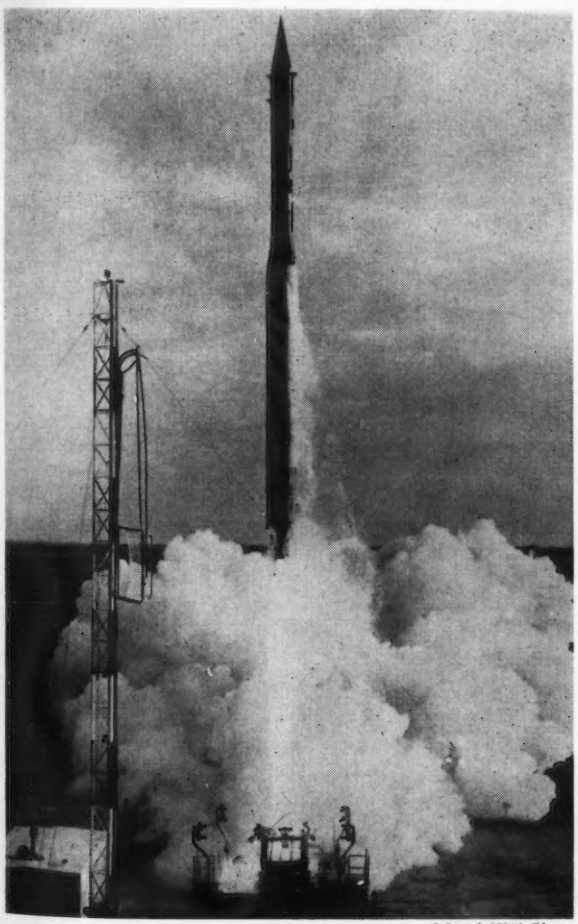


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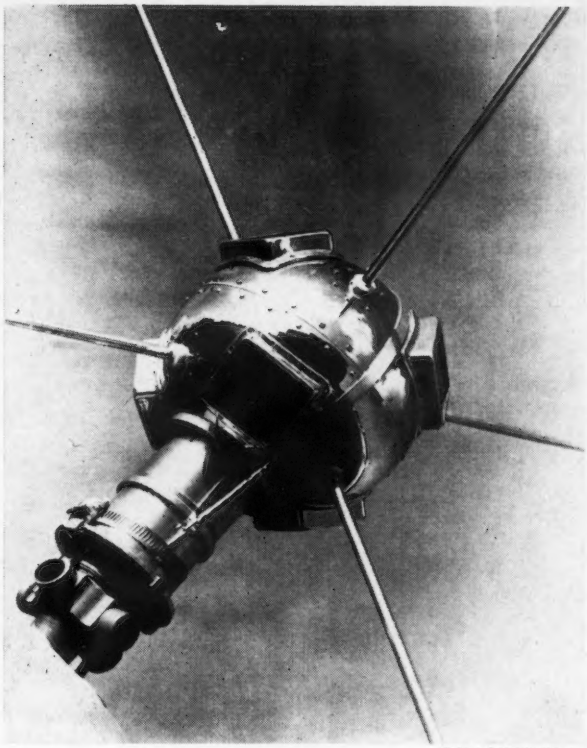
Figure 5

Firing of the USN Vanguard rocket, Cape Canaveral, 17th March, 1958



Official USN Photo

Figure 6

Test sphere mounted on the end of the third stage of the Vanguard rocket

The IGY program has already revealed many interesting facts and will undoubtedly continue to provide information[9] which will form the basis for future experiments. Figure 7 illustrates the orbits of the first satellites as they would appear if they had been launched from the same point into the same plane through the earth's centre. The orbital height is exaggerated by a factor of two for clarity of illustration. The following facts are of interest:

(a) Sputnik I, which had the lowest orbit, and Sputnik II have both already re-entered the atmosphere and either burned up or impacted, as have also the final stage rocket and nose cone of Sputnik I. Sputnik I lasted 92 days and Sputnik II 162 days.

(b) Sputnik II, which was in a more eccentric orbit than Sputnik I, weighed 1,118 lb and was, therefore, the heaviest of the satellites at the time of its launching. The fact that the dog, carried by its air-conditioned compartment, lived for several days and many orbits around the earth demonstrates that it may be possible for men to exist in satellites or space ships. However, a recent Russian announcement indicates that insufficient information was obtained on this point and that return of an animal-carrying vehicle from orbit is an essential next step.

Satellite	Launching Date	Orbital Period	Perigee Miles	Apogee Miles	Wt. Lbs.
SPUTNIK I	4 Oct. 57	96.2	143	583	184
SPUTNIK II	3 Nov. 57	103.7	130	1056	1120
SPUTNIK III	15 May 58	106	137	1175	2919
EXPLORER I	31 Jan. 58	114.9	219	1589	30.6
EXPLORER III	26 Mar. 58	115.7	110	1738	30.8
VANGUARD I	17 Mar. 58	135	407	2513	3.25
FUTURE CIRCUMLUNAR SATELLITE	1958?		200?	At least 250,000	20-50

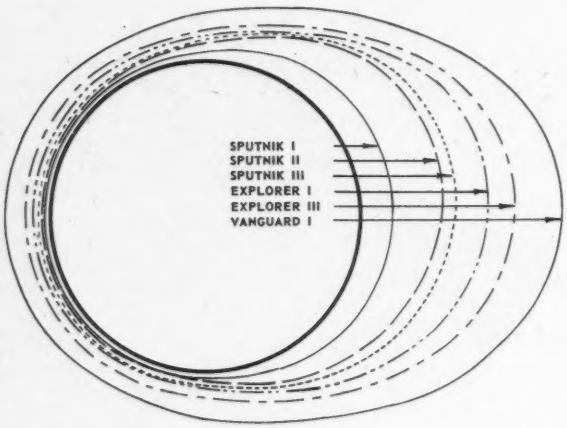


Figure 7

Earth satellite orbits
(Orbital altitude exaggerated by a factor of 2)

(c) The rate at which satellites are slowed up depends on the density of the atmosphere[10, 11]. The information obtained from the satellites indicates that the density of the atmosphere at 150 to 200 miles altitude is as much as twenty[12, 13] times higher than had been previously estimated.

(d) Explorer and Vanguard satellites, which were placed in higher orbits because of the excessive decay rates of Sputniks I and II, can be expected to have longer lives.

(e) The Russian satellites are in orbits at an angle of about 65° to the equator and, as the earth rotates inside the orbit, these satellites pass over all of the earth between the Arctic and Antarctic circles.

(f) The American satellites, which are launched from Patrick Air Force Base at Cape Canaveral, Florida, are in orbits at an angle of about 35° to the equator and cover the earth only between the latitudes of 40°N and 40°S.

(g) Because the earth is not a perfect sphere a satellite orbit tends to precess around the centre of the earth. Sputnik II, which was at its lowest altitude near its launching point, was originally quite low when it passed over Canada. However, the precession finally moved the perigee south to about the equator and it would have been necessary to go far south for as good a view as was available in Canada in December.

(h) The temperature measurements taken by Explorer I have recently been published[14]. They indicate that the methods used to control the internal temperature of the satellite have been successful in keeping it between 50° and 110°F — quite reasonable limits for human endurance. The skin temperature lies between 63° and 173°F.

(i) Cosmic ray measurements made in Explorer satellites indicate[12, 15] intense cosmic ray radiation at about 600 miles elevation. Although insufficient evidence is available to establish the level, present interpretation is that the geiger tubes of the Explorers were saturated at a level of 35,000 counts per second. Dr. Van Allen is reported to have estimated the radiation level inside the satellite to be about 0.06 roentgens per hour, a dose rate which would give a man the maximum weekly quota of 0.3 roentgens in five hours. It seems that lead or other shielding is likely to be necessary for manned space vehicles.

INSTRUMENTED MOON ROCKETS

The next phase in space experimentation will be exploration of the moon using techniques similar to those used for launching earth satellites. There are a number of possible approaches, including impact on the moon, orbit and return to earth, and establishing an instrumented satellite around the moon to make measurements similar to those of the artificial earth satellites. Eventually these instrument carriers might be landed on the moon and remotely controlled to explore and send back information. A Russian paper[16] describes a tank-like radio-controlled tracked vehicle which could be driven about on the surface of the moon with television cameras and scientific instruments to measure and transmit data to radio receivers on the earth.

Both the Russians and the Americans have moon rockets in construction which are expected to be capable of striking the moon or orbiting near to it. We can expect this event to happen at any time. Little is known of the Russian program but two American agencies have moon rocket projects. The US Army has been authorized to use Jupiter C, Figure 3, with additional stages, and the USAF is expected to combine the Thor IRBM, Figure 2, with Vanguard, Figure 5, second stage and a new third stage. The Thor-Vanguard combination has reportedly been fired in a ballistic orbit to a distance about 5,000 miles down range from Cape Canaveral, Florida.

There are a number of different ways[17, 18] by which a rocket might be fired to the moon. However, the most practicable method appears to be a simple extension of the earth satellite technique. There are practical difficulties because of the geometry of the moon's orbit relative to the earth and the particular launching site. If maximum payload is to be carried for a given rocket, it will be necessary to reach the moon near the apogee of an artificial earth satellite's orbit. For minimum energy, a launching site within 15° to 29° (depending on time of launch) of the equator would be required. However, if a polar orbit is used, it seems possible to strike the moon or orbit near to it from present launching sites. The

accuracy[19] demanded for a moon strike is, however, much higher than that required for an earth satellite. The velocity will have to be accurate to about 100 ft/sec in 35,000 and the angle of launch must be within about 0.2°.

The first moon rocket vehicles[20, 21] will undoubtedly be relatively small but plans are being discussed for increasing the payload. It has been stated by Ehricke[22] that Convair has completed preliminary designs for a 200 ft, 90 ton, two-stage, chemo-nuclear vehicle capable of landing a payload of 22,000 lb on the moon. He suggests that during 1958-60 shooting to the moon, circumnavigating it, establishing a satellite around it and making a controlled landing on it are possible. He goes on to suggest that during 1964-70 it will be possible to land instrumented vehicles on the moon, send out manned rockets for lunar reconnaissance and, finally, to land small scouting parties. An extensive timetable for the development of manned space flight over the period from 1957 to 2100 AD is given in a recent special report on space flight[23]. This timetable also forecasts lunar exploration by 1970 but goes on to predict manned Venusian exploration in 1985, Martian exploration in early 1990's, solar system reconnaissance by 2000, and exploration outside the solar system by 2045.

MANNED SATELLITES AND SPACE VEHICLES

Both Russian and American plans include sending manned vehicles to the moon. If these lunar voyages are to be made, a manned vehicle will be necessary and the technique must be developed. The USAF X-15 is designed to fly short hops between two air bases on ballistic trajectories up to altitudes of 200 miles. These altitudes correspond to those of satellite orbits and all the same environmental conditions will be encountered for short periods. The re-entry manoeuvre will be undertaken on each flight.

More advanced manned satellite proposals, including vehicles which would perform one or more complete orbits before re-entry, have also been announced[24] and some of these may be undertaken in the near future. As the technique is improved by short hops, the manned vehicle will be placed in orbit with the capability of re-entering at a predetermined point on the surface of the earth. During these flights the problems associated with crew protection, weightlessness, isolation, artificial cabin control, long duration missions, space navigation etc., will be explored and solved.

When the problems of manned satellite flight have been solved, the propulsion problem arises again when longer flights are considered. The manned satellite will have the velocity of 18,000 miles/hr or 5 miles/sec required to remain in orbit outside the earth's atmosphere. If longer space flights are to be undertaken, it will be necessary to attain the velocity to escape from the gravitational field of the earth and travel in the field of the sun. Since the gravity force varies inversely as the square of the distance from the centre of the earth, it is decreasing rapidly as altitude is increased, and an additional 7,000 miles/hr or 2 miles/sec velocity will bring the satellite velocity up to the 25,000 miles/hr or 7 miles/sec necessary to escape from the earth's gravitational field entirely. If the vehicle is headed in the right direction when it attains "escape velocity", it can be made to coast to a wide selection of destinations. However, it will be necessary to attain escape velocity with a space vehicle carrying enough fuel to land on and return from the moon or one of the planets, if a successful return is to be made. The extra fuel required for return puts a serious strain on the propulsion techniques and larger thrust engines or refueling techniques will be necessary before these flights will be possible.

Ideally, we would like a rocket-type reaction motor of much lighter weight using a fuel with greater energy per pound. Projects for improving rocket propulsion in the future have been described above. There is, however, another point in our favour. If a manned satellite orbit can be established with chemical fuels the orbit decays at a very slow rate and the additional velocity required to attain escape velocity could be built up more slowly without great disadvantage. Thus a relatively low thrust motor could be used to gradually increase the velocity of the satellite vehicle. Solar or ion engines might be used for this purpose.

SPACE STATIONS AS REFUELING POINTS

Another device common to both science fiction and serious literature is the space station. If you consider that a satellite might contain fuel tanks instead of instruments, it is possible to visualize a space station being built up as a refueling station circling about the earth on a stable orbit similar to those of the present earth satellites. A manned space craft could then rendezvous with the space station and refuel before leaving for space destinations. A serious proposal[25] to establish a manned space station of some 15,000 lb using seven Atlas rockets to carry the component parts into the orbit has been made by Convair.

There is much that could be written on the subject of space station development, but it is reasonable to assume that either a satisfactory space station or improved rocket motors of the atomic, solar or free-radical type will be available to accelerate a space ship to the escape velocity with a load of fuel sufficient for it to return to earth after a space mission. The capability to return means, of course, that it will have enough fuel to exceed the escape velocity of the planet of destination and enough to manoeuvre into a stable orbit about the earth on return. In this respect it is interesting to note that the fuel required for a manned space ship to rendezvous with a space station is more than that required for a flight to the moon and return.

SPACE TRAVEL

Examination of Figure 8 indicates that, although the propulsion problem of space travel is extremely difficult, it is not impossible. If we consider the fact that all of the planets are travelling about the sun in practically the same plane, it will be realized that the velocity of the earth around the sun will contribute to establishing a solar orbit for a space vehicle. If the vehicle leaves the earth with the correct direction and time, a velocity only slightly greater than the escape velocity is required to establish an orbit about the sun which would intercept the planet of destination.

The establishment of a 3,000 lb satellite in orbit is only a very early indication of future capability for space exploration. An energy increase of about 50% is

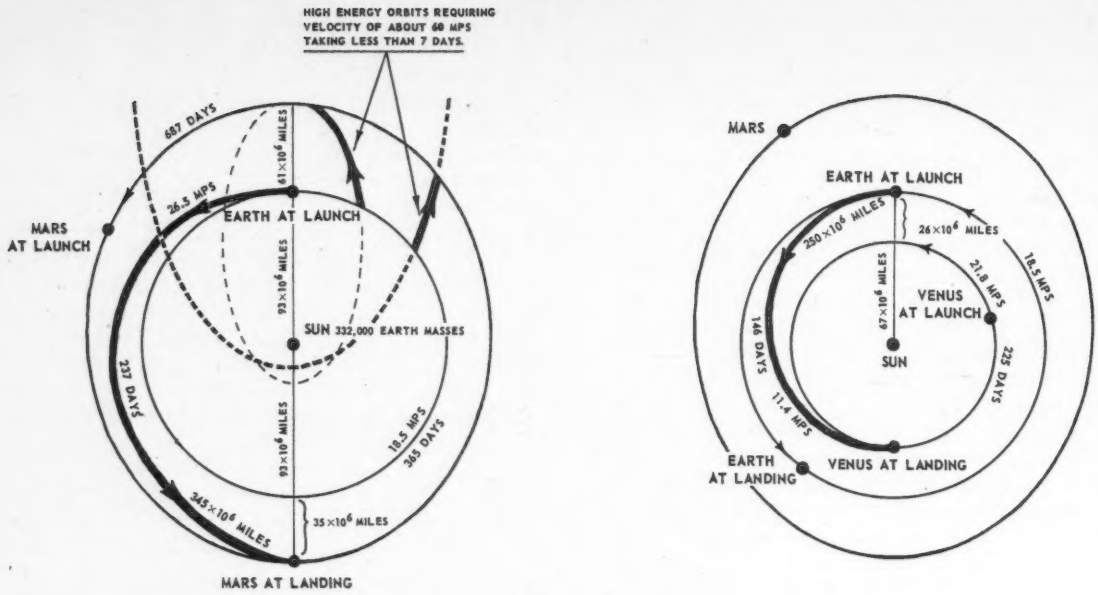


Figure 8

Solar orbits[8, 26] for space travel to Mars and Venus

sufficient to cause an equivalent mass to orbit out to lunar distances and a further increase of only about 3%[8] is required for orbits to Mars or Venus. The facts indicate that the capability for instrumented lunar and planetary exploration are now within reach.

The planets of greatest interest for near future exploration are Venus and Mars. Venus is on an inferior orbit and Mars on a superior orbit to that of the earth. Typical low energy orbits that might be followed to Mars and Venus are illustrated in Figure 8. Undoubtedly the first trips to the moon or either of these planets will be return trips, with the space vehicle orbiting about the planet a number of times until the earth is in a suitable position and then accelerating sufficiently to return. Since the moon, Venus and Mars are all of much smaller mass than the earth, the "escape velocity" and therefore the fuel for return is somewhat smaller than that required to escape from the earth. There is, of course, the possibility of leaving fuel tanks established in orbit around these remote planets. In this way a reserve of fuel could be built up against the time when it is desirable to land. By doing this, the space ship could avoid the necessity of carrying the fuel for overcoming the difference between the orbital velocity and the escape velocity down to the surface of the planet and up again to orbital height.

Consideration of the problems of travel to the moon and the near planets has been continuous. Contributing to difficulties of travelling to the moon is the fact that the moon has practically no atmosphere and that it is very hot during the lunar day and very cold at night. To live there would require the establishment of dwellings, workshops and vehicles pressurized and air-conditioned in a fashion similar to that of high altitude aircraft. Dwellings will likely be underground, or constructed as heavy stone igloos, to contain the pressure of an artificial atmosphere and give protection against heat, cold and meteors.

Arthur Clarke[26] and R. A. Smith[27] have put forward concepts for a future lunar colony, including permanent dwellings, hydroponic farms, communication centres, space port, oxygen and water supplies etc. Those who are interested in space exploration can find fascinating reading in a large number of books and publications on the subject. Typical examples are listed among the references to this paper. In spite of the difficulties of establishing a permanent colony there, the moon has many advantages as an intermediate station in space travel. It has an escape velocity of only 2 miles/sec and already possesses a velocity corresponding closely to the earth's solar orbital velocity. Particularly if local rocket fuel could be found or manufactured, it would become an important stopping point for travel to more distant destinations.

Although it is possible to become quite enthusiastic and imaginative about space exploration, the unsolved problems have a sobering influence on those who give serious consideration to practical aspects of future space travel. While propulsion remains as one of the major hurdles, problems in structures, re-entry technique, space navigation and rapid computing of multiple gravity field orbits, guidance and control of space ships, communication, human factors, provision of food and oxygen, waste processing and reliability of equipment are all areas requiring intensive research before design of practical vehicles for space exploration can be undertaken with confidence.

SPACE EXPLORATION PROJECTS

The provision of a practical space vehicle will provide a new tool for research projects to explore the unknowns of space. Progressive investigation will probe the regions surrounding the earth, the earth-moon or

cislunar region, the near planets, Venus and Mars, the outer planets of the solar system and, eventually, the extra-solar, interstellar or intergalactic regions. A very long list of research investigations could be drawn up for each of the regions and if the list is restricted to earth and moon only, there are still a very considerable number of interesting investigations on which a start can now be made. The IGY program is using earth satellites to get information about the earth's magnetic field, the level of solar and cosmic radiation, the mass and shape of the earth, accurate intercontinental mapping, the density of the upper atmosphere, and nature and composition of the dust and atomic or molecular fragments obtained in space, the mapping of cloud cover as an aid to meteorology, the temperature equilibrium of satellites orbiting in space etc. Preliminary information in many of these fields is already available, including a number of unpredicted results. Future experiments can be expected to provide new information which will affect the future of mankind. It has been suggested[9], for example, that earth satellites could be used to reflect sufficient sunlight to provide a level of artificial moonlight which would illuminate the whole earth, allowing continuous daylight operation, reducing the power requirement for artificial illumination, increasing crop yields and having many other effects which could not be foreseen.

As the exploration moves out to the moon and the near planets, it will be of interest to establish whether or not they have magnetic fields, the nature and density of the atmosphere, the mass and composition of the materials forming the planets, the nature and origin of lunar rays and craters, the existence or otherwise of plant or animal life. As the exploration expands, an increasing number of interesting investigations will be revealed.

NEW ATTITUDE OF ASTRONAUTICS WILL STIMULATE RAPID PROGRESS

The launching of earth satellites has already had a great impact which has stimulated a reassessment of what is known about space science. Although the reassessment has revealed a considerable body of information, it is infinitesimal compared with the information which is likely to be derived within the next decade. New information has already been obtained from space experiments but this information is relatively unimportant when compared with the impact which a completely new intellectual environment for the scientific world, and a completely new attitude to space science on the part of the whole human race, will have on the future of science.

The new interest in astronautics is reflected in the very high rate of publication of popular and serious information on the subject and in the willingness to commit extensive financial support to space research programs. A recent US estimate of the build-up of the space budget indicates[28] that two billion dollars will be spent by the end of 1958, and that fifteen billion dollars will be spent by 1970. The challenge of space is before the world and the new attitude to space exploration can be expected to stimulate rapid progress.

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THE RCAF APPROACH TO THE EVALUATION OF A SUPERSONIC INTERCEPTOR ARMED WITH AIR-TO-AIR GUIDED MISSILES†

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INTRODUCTION

THE evaluation of a supersonic interceptor armed with air-to-air guided missiles is a subject that has been given, and is being given, a great deal of thought by many people in and out of the RCAF. The subject is a broad one; however, it is hoped the detail given here will be sufficient to give a reasonably clear picture of the RCAF approach to the evaluation.

DEFINITIONS

A few definitions are necessary before the general subject is discussed.

Weapon System

The common phrase used in and out of the RCAF today is "weapon system". A "weapon system" includes the aircraft, the ground support equipment and the necessary aerodrome facilities required to enable the airborne part of the weapon system to be maintained in a state of readiness, to get airborne, land and be turned around in the time periods specified. This "system" should not be confused with the "Defence System" which includes, as well as the weapon system, the radar networks, the intercept control facilities and all the administrative and logistic organization that goes along with it. The airborne portion of the weapon system is the aircraft which contains an electronic system and carries air-to-air guided missiles.

Electronic System

The electronic system includes the airborne radar, the telecommunications system, the navigation system, the automatic flying control system and other electronic equipments. This electronic system provides the all weather, day and night intercept capability to the airborne part of the weapon system.

Ground Support Equipment

The ground support equipment includes all the movable equipment required on the ground to maintain the airborne part of the weapon system, to turn it around or to keep it in a state of readiness. The variety and amount of equipment required for these purposes are increasing in proportion as weapon systems become more complex and as the time periods for readiness and scramble are compressed.

WEAPON SYSTEM EVALUATION

The RCAF evaluation of any new weapon system begins long before any hardware is designed or produced and is a continuing process until well after the squadrons are initially equipped. This continuing evaluation includes the Mock-Up Review Boards which evaluate wooden and/or metal mock-ups and Engineering Evaluations which are conducted on the first or second aircraft built. The portion of the evaluation programme that this paper covers in some detail is the flight test part of the overall evaluation.

The RCAF some time ago drew up and defined eight different stages or phases to cover the total flight test evaluation required for the airborne part of the weapon system. These phases were patterned to some extent on those used by the USAF (see Figure 1).

Phase 1	— Contractor	— Airworthiness and Equipment Functioning
Phase 2	— RCAF	— Preliminary evaluation
Phase 3	— Contractor	— Check out modifications
Phase 4	— RCAF	— Complete performance and handling trials
Phase 5	— RCAF	— All weather evaluation
Phase 6	— RCAF	— Intensive flying trials
Phase 7	— RCAF	— Aircraft weapon system evaluation
Phase 8	— RCAF	— Operational suitability trials

Figure 1: Flight Test Evaluation Phases

Phase 1 — Airworthiness and Equipment Functioning

This phase is carried out by the Contractor and includes ground functional checks on the aircraft systems prior to the first flight and the initial flying programme on the aircraft to check it out as a flying machine over as much of the flight envelope as possible. The total amount of flying time accumulated during this phase varies with the type of aircraft and depends to a great extent on the problems that are encountered but should vary somewhere between 100 and 150 hrs.

†Paper read before the Ottawa Branch of the C.A.I. on the 12th February, 1958.

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Phase 2 — Preliminary Evaluation

This phase is conducted by the RCAF, usually at the Contractor's plant to get an initial first hand appreciation of the handling characteristics and performance of the aircraft. Total flying time is approximately 30 hrs.

Phase 3 — Check out Modifications

This phase is carried out by the Contractor to check-out improvements or changes found necessary as result of tests in other phases.

Phase 4 — Complete Performance and Handling Trials

This phase is carried out by the RCAF at an RCAF test base. Extensive quantitative data is acquired during this phase by the RCAF to check and complete Pilots Operating Instructions for the aircraft. The flying time required is approximately 150 hrs.

Phase 5 — All Weather Evaluation

This phase is carried out by the RCAF at an RCAF test base to evaluate the weapon system on the ground and in the air under extreme weather conditions.

Phase 6 — Intensive Flying Trials

The object of this phase is to build up a maximum number of flying hours in as short a time as possible to establish the reliability of airframe components and installed equpiment, to evaluate the ease of maintenance, determine the rate of parts consumption and establish personnel requirements for maintaining the aircraft in squadrons. This phase is conducted by the RCAF at an RCAF base.

Phase 7 — Aircraft Weapon System Evaluation

This phase covers the airborne part of the weapon system to determine its kill capability against specified targets. It is carried out at an RCAF base. This phase will be discussed later in some detail.

Phase 8 — Operational Suitability Trials

This phase covers the complete weapon system to check it out in the defence system as a whole and work out tactics that will ensure a maximum effectiveness for the whole defence system.

The above phases, when completed, should have provided a very comprehensive and exacting evaluation of the weapon system. This will come about, however, only if careful planning is carried out leading up to the various phases to ensure that all the necessary support equipment, base and range facilities and trained personnel are available when required and in the quantities required. This detailed planning involves quite a large number of RCAF personnel and, of course, Contractor's personnel.

Each phase must, of course, be carried out successfully and in the shortest possible time in order to gain the maximum benefit. The preparations leading up to each phase are, therefore, of utmost importance to ensure that a maximum and sustained effort can be made in carrying out each phase once it begins. Note that Phases 2, 4, 5 and 7 are carried out by the Central Experimental and Proving Establishment, or CEPE as it is commonly referred to, and Phases 6 and 8 by the appropriate Operating Command. The writer is most familiar with the phases CEPE are responsible for and most of the following details will be confined to these phases.

FLIGHT TEST WORK

The type of flight test work involved during Phases 4, 5 and 7 can best be covered by outlining some, if not all, of the objectives for each of these phases.

It should be noted the RCAF intends to be closely associated with all the Contractor's flight test programmes while they are in progress in order that detailed knowledge of the capabilities of the weapon system be acquired long before the RCAF phases begin. This should enable the RCAF to carry out service programmes in a highly efficient manner and avoid duplicating something that already had been carried out satisfactorily by the Contractor.

The objectives of the CEPE phases are as follows.

Phase 4 objectives are:

(a) To measure performance which includes landing and takeoff, climb, maximum and minimum level speeds, range, turning and descent performance. One problem associated with performance is that of measuring thrust, which is difficult when the afterburner is operating due to the high temperatures generated. Performance tests will be carried out with and without afterburners operating.

(b) To assess stability and control which includes longitudinal, directional and lateral stability in every configuration in which the aircraft is liable to fly within the allowable centre of gravity and weight ranges, with and perhaps without the damper systems operating.

Phase 5 objectives are:

(a) To assess the capability of the engines in the aircraft to start after cold soaking for various periods of time at moderate and extreme, low ambient temperatures.

(b) To assess the capability of all systems in the aircraft to function satisfactorily after soaking the aircraft in extreme, low and high ambient temperature conditions.

(c) To assess the tracking capability of the airborne radar system in rain and snow.

(d) To assess the characteristics of the aircraft during blind approaches, that is in rain, snow, or heavy overcast.

(e) To assess the flying characteristics of the aircraft during moderate to extreme icing conditions.

The Phase 7 programme which is the phase covering the engineering evaluation of the airborne portion of the weapon system is by far the most complex part of CEPE's evaluation programme. The preparations leading up to this phase of the evaluation must be most thorough. These preparations can be divided into two major aspects; the design of the experiment or programme of events and the development of a suitable evaluation system.

DESIGN OF THE EXPERIMENT

In the design of the experiment the objective is to determine how many and what kind of "shoots" are required to successfully complete the evaluation programme. A "shoot" is a flight test exercise which may

or may not involve the actual firing of missiles. Initial shoots are conducted carrying "captive" missiles in order to determine as many faults in the electronic system and missile as possible without actually firing the missile(s). These shoots are called "dry runs". The fewer the number of shoots carried out, the less expensive is the programme. Two items that may be expended during any one shoot are of course the missile and the target. If one each were expended per shoot the cost per shoot could well exceed the total salary of an RCAF engineer for more than a ten year period. It is essential, therefore, that the number of shoots be kept to a minimum but it is also essential that the evaluation programme be carried out thoroughly and successfully and in a reasonable time period. The best engineering brains available will be brought to bear in the design of the experiment in order to ensure the most satisfactory and the most economical programme is worked out. To explain the approach in simple terms is difficult; however, an attempt to do this is given below.

It should be remembered the overall objective of the weapon system evaluation is to assess quantitatively the functional capability of the weapon system to counter an enemy air threat, to determine the deficiencies in the system which will prevent it from achieving this goal and to make recommendations for the improvement of these deficiencies. Some of the detailed objectives within this general objective are:

(a) To assess quantitatively the effectiveness of the weapon system in terms of kill probability throughout the altitude and speed ranges of the aircraft; which means the missile warhead effectiveness and target vulnerability should be known or determined, together with the variation of accuracy when the attack vector, the launching speed, the launching range and the altitude are varied.

(b) To assess the electronic counter countermeasure capability of the weapon system and recommend procedures and modifications to improve this capability.

In order to assess anything quantitatively, it is necessary to convert all aspects that are involved to mathematical relationships. These mathematical relationships will not be given here but the complex nature of the problem will be pointed out. There are three major pieces of equipment involved in a shoot—the aircraft, the missile and the target. The aircraft contains a complex electronic system, the missile contains a guidance and control system, while the target may be a relatively simple piece of equipment.

However, in order to assess realistically the kill capability of the weapon system it should be appreciated that the target used in the evaluation should have speed, altitude and radar reflectivity characteristics comparable with those of the enemy threat. If this type of target is not available, data gathered by firing at inferior type targets must be extrapolated. The characteristics of the target that is used must be known in detail by the designers of the experiment. This will eliminate some variables from the equations and simplify matters to some extent.

In designing the experiment all objectives are translated into mathematical objectives by constructing a theoretical framework which is based on mathematical relationships between sub-systems and by relating the whole system using equations containing selected basic parameters. The whole system is composed of the aircraft, the missile and the target. Equations or formulas must be written expressing the parameters in terms of measurable quantities. A logical set of measurements must be made so that the entire chain of events during an attack may be followed. The final determination of the parameters to be measured will come about through detailed knowledge of the electronic system, the missile and the target.

With the construction of the theoretical framework, the values of variables, such as altitude, speed, launch conditions and others which should be chosen, can be determined and the actual number of shoots required can be worked out.

THE EVALUATION SYSTEM

The evaluation system comprises all facilities and equipments required during an evaluation programme (see Figure 2). Included are:

(a) Base Facilities
- Adequate runways
- Hangarage and office space
- Laboratories
- Personnel housing
- Data reduction and computing facilities
- Maintenance and check out facilities for missiles and aircraft, including the electronic system

(b) Range Facilities
- Adequate range area
- Ground data acquisition systems (kinetheodolites and telemetry ground stations)
- Precision radar and plotting systems
- Control facilities (for control of all activities both on the ground and in the air during a shoot)

(c) Support Equipment
- Targets
- Target ancillary equipment such as miss distance equipment, drone support equipment including drone recovery equipment
- ECM equipped aircraft
- Chase aircraft
- Adequate data acquisition systems in aircraft and missiles
- All other necessary ground support equipment

(d) GCI Radar Facility

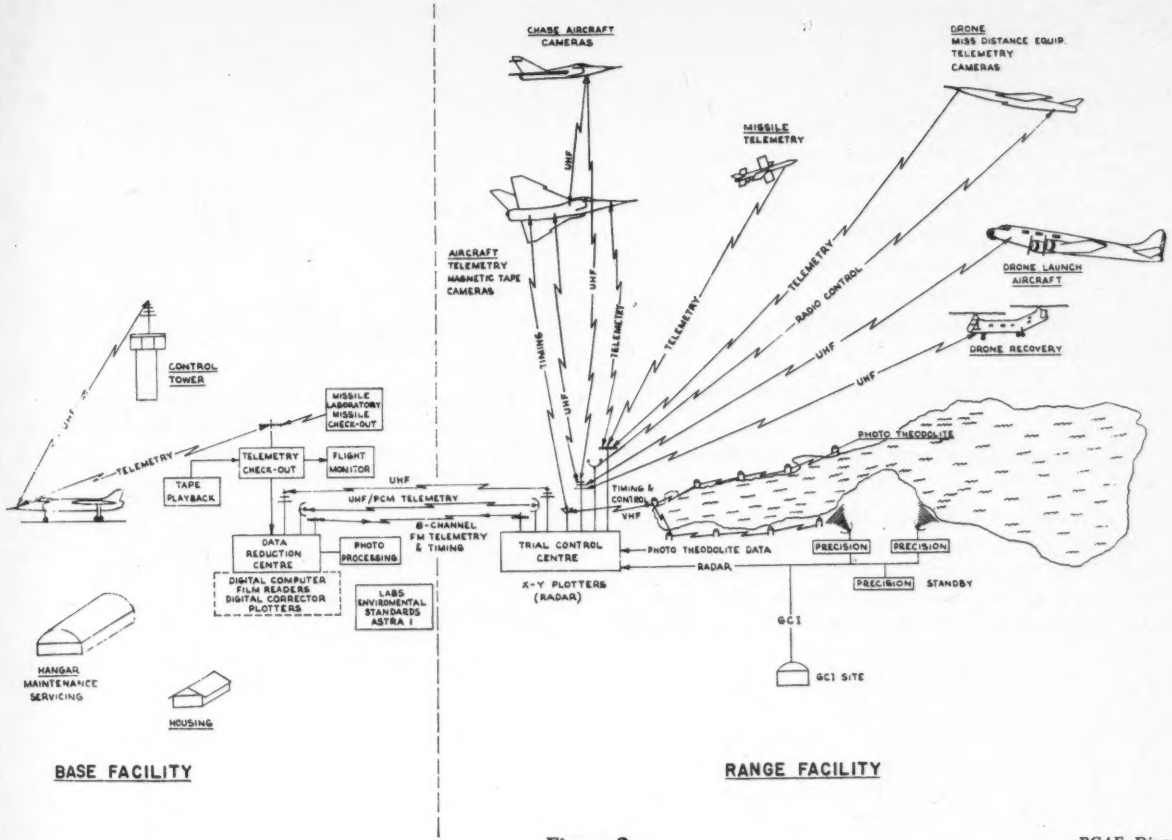

Figure 2
Evaluation System

RCAF Diagram

Some of the items included in this evaluation system are self-explanatory and will require no discussion. Some will be discussed in detail. Initially it is necessary, however, to understand the extent to which the evaluation system will be used. It was stated before that Phase 2 would be carried out at the Contractor's and Phases 4, 5 and 7 would be carried out at RCAF test bases. For the evaluation of a complex weapon system the logistics, personnel, data handling and many other problems will be simplified if the latter three phases are carried out using one evaluation system. Thus one evaluation system will be used for Phases 4, 5 and 7. Also the principal Contractor is required to demonstrate the weapon system before the Phase 7 programme begins. The evaluation system must be used by the Contractor for work prior to and during the actual demonstration. Thus a suitable evaluation system will be a very important factor in the successful evaluation of the weapon system. Phase 7 and the Contractor's demonstration programmes will require the use of all the items in the evaluation system; Phases 4 and 5 will require the use of only some of the items. With proper planning and scheduling it will be possible to have two or more of these programmes run off simultaneously within the evaluation system.

DATA ACQUISITION AND DATA REDUCTION

One group of items in the evaluation system that will be discussed in some detail are all those items associated with data acquisition and data reduction. It should be appreciated that the gathering of data, its reduction to a readable form and the analysis of the results is the prime requisite of any evaluation programme. Thus it is absolutely necessary in the evaluation of a weapon system, where time is so important, that the most modern and automatic methods of gathering and handling data are used. The present day methods of acquiring data are:

Airborne Equipments – Cameras (Photo panels)
Oscillographs
Magnetic Tape
Telemetry

Ground Installations – Kinetheodolites
Telemetry Station

The time required to develop film, make prints and read off the data is a slow process at best and always laborious. However, cameras cannot be discarded altogether for the purposes of recording data and events. Oscillographs offer a flexible method of data acquisition and data reduction. They are limited, however, in the number of parameters that can be measured at any one time and require manual operations during read-out and reduction. They serve a purpose, where only monitoring of parameters is required.

A magnetic tape system offers many advantages in the business of data acquisition and data reduction and analysis. The chief advantages associated with magnetic tape are:

(a) More data can be collected during one flight.

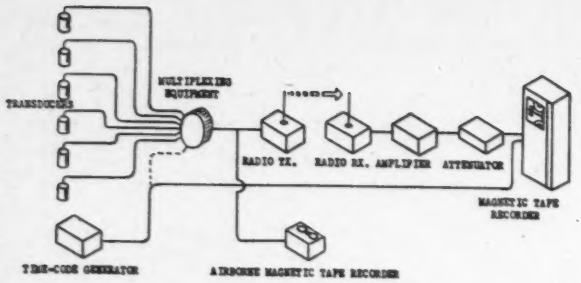

Figure 3
Data Acquisition by Magnetic Tape

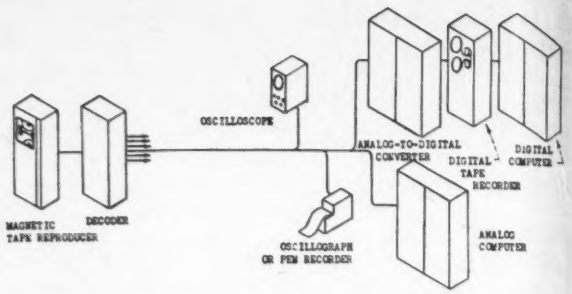

Figure 4
Data Reduction from Magnetic Tape

(b) Automatic reduction of the data to readable form is possible.

(c) The data can be fed into a computer for analysis with no manual read-out required.

This type of system thus provides the means of acquiring, reducing and analyzing a large volume of data in a relatively short period. It is not without its disadvantages because it is more expensive initially than other systems and it may require more maintenance and calibration checks.

There have been many varieties of magnetic tape systems produced in the U.S. This variety tended to create quite a chaotic condition, particularly when extensive additional equipment was required on the ground for data reduction purposes. This situation was recognized some time ago by the various agencies in the U.S. and the Inter Range Instrumentation Group formed a standardization committee to agree on suitable standards for magnetic tape systems. The RCAF has now adopted these IRIG standards for magnetic tape systems.

A simple magnetic tape airborne data acquisition system is shown in Figure. 3. This system consists of transducers, multiplexer and amplifier equipment and the magnetic tape recorder and/or the transmitter if telemetry is being used. A transducer is a gadget that transforms basic raw data into electrical currents. These currents are amplified and scrambled to some extent before being recorded on the magnetic tape. The tape is one inch wide and will carry 14 tracks of information. With suitable commutation and multiplexing it is possible to simultaneously record information from approximately 250 transducers on the tape.

Having recorded the information it will be necessary to get the information off the tape, unscramble it and bring it out in readable form. This means playing the tape back using a reproducer which is essentially the same as the recorder. One track of information is played back at a time and the information supplied by each transducer can be fed into an oscillograph and/or oscilloscope. If the information from 40 transducers were recorded on the one track, then there would be 40 traces on the oscillograph. Simultaneously with this playback the information is fed through an analog to digital converter and recorded on tape again, only now in digital form. The project engineer then will determine by looking at the traces on the oscillograph what information should be further reduced. He may decide that only 8 traces need further reduction and perhaps only information at various intervals of some minutes is required. It is possible to pick out these 8 traces now recorded in digital form and with an automatic search and control unit to cover the exact times the information is required. These pieces of information are then put through a scaler and corrector and can be plotted automatically on an X - Y plotter or fed directly into a digital computer. This data reduction system is shown in Figure 4. In this manner a vast amount of information can be recorded and processed quickly with manual operations being practically non-existent. Only in this manner is it possible for evaluation programmes to be run off on any kind of predetermined schedule.

It should be noted that there is still going to be some data collected on film, during the Phase 7 programme particularly. This film will be from the kinetheodolite cameras on the ground and from the cameras that may be in the interceptor and target aircraft to record the trajectory of the missile and perhaps the "miss distance" between the missile and the target. This whole problem is being studied, however, to try and find some means of recording the information so that automatic methods of processing this data can be used.

TRIALS CONTROL CENTRE (see FIGURE 5)

This is one other item in the evaluation system that will be discussed. This centre is responsible for controlling all the activity during a shoot and could be considered as the "brain" of the evaluation system.

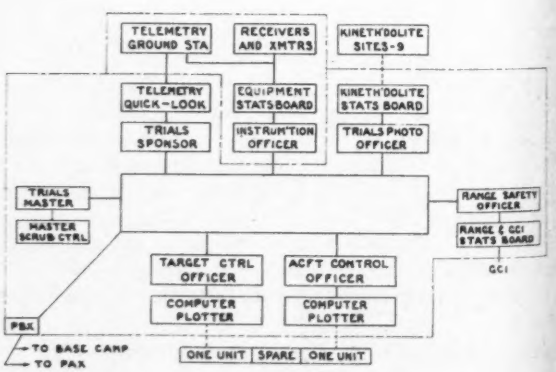

Figure 5
Schematic of Trials Control Centre

There are eight people operating in this control centre during a shoot. Information is fed to these people by radio and telephone. Each person has definite responsibilities and knows from the equipment in front of him or by regular verbal reports coming in by radio or telephone that everything is behaving as it should be.

The key man during a shoot is the Trials Master who knows exactly what each airborne vehicle is required to do and the timing that needs to be adhered to. Proper timing is absolutely essential if the impact between the missile and target is going to take place within the confines of the instrumented range. This timing becomes most acute when speeds of both the aircraft and target increase to supersonic values. The Trials Sponsor is usually the project engineer and is particularly interested in the information coming through on telemetry from the aircraft and missile. The Instrumentation Officer keeps tab on the functioning of all telemetry and radio equipment being used on the ground. The Photo Officer keeps tab on the functioning of all kinetheodolite cameras. The Range Safety Officer by means of information from the GCI keeps tab on all airborne activity. The Aircraft Control and Target Control Officers keep track of and direct the aircraft and target respectively. All these people are in direct contact with each other and any one of them may indicate that an exercise should be scrubbed due to some malfunction or because the timing is off.

There are other items in the evaluation system that should perhaps be discussed. However, it is hoped that by discussing the data acquisition and data reduction systems and the Trials Control Centre an appreciation of the complex nature of some of the equipment in the evaluation system and the complexity in the operation of the evaluation system will have been achieved.

JOINT I.A.S./C.A.I. MEETING

CHATEAU LAURIER

OTTAWA

7th and 8th October, 1958

October 7th . . .	Morning—9.00 a.m. to 12 noon . .	Aeromedicine	Concurrently
	Morning—9.00 a.m. to 12 noon . .	Aeroelasticity	
	Afternoon—2.00 p.m. to 5.00 p.m. .	Propulsion	Concurrently
	Afternoon—2.00 p.m. to 5.00 p.m. .	Environmental Testing	
	Evening—7.00 p.m.	Dinner	
October 8th . . .	Morning—9.00 a.m. to 12 noon . .	Aircraft Actuating Systems	Concurrently
	Morning—9.00 a.m. to 12 noon . .	Materials	
	Afternoon—2.00 p.m. to 5.00 p.m. .	Test Flying	

WHAT'S THE SCORE ON TURBINE FUEL?†

by C. Campbell*

Orenda Engines Limited

INTRODUCTION

ALTHOUGH the jet driven airplane is now commonplace, in fairly wide civil use and in almost exclusive military use, this does not mean that all of the problems associated with the operation of jet engines have been overcome.

This paper constitutes an attempt to review as dispassionately as possible the existing turbine fuel handling techniques and, in passing, to form an opinion on the relative merits of Kerosene and JP4 based purely on observation of such techniques and on operational experience. It is hoped that this will be helpful towards doing all that can be done with existing equipment to ensure maximum safety, reliability etc., and will impress people at the operating level with the importance of their tasks and the very real responsibility which is theirs. It is also hoped that people responsible for the operation of turbine engine aircraft who do not already have live educational programs in connection with fuel handling will consider instituting such programs. The dividends will be very high.

Contrary to opinions publicly expressed by well known people in the industry, the present turbine engine fuel system is many times more sensitive to contamination than ever its older "reciprocating brother" was. A growing appreciation of this fact, based in most cases on very painful operational experience, has given rise to a number of excellent papers; e.g. References 1, 2, 3 and 4. The oil companies are bending their efforts to satisfying the requirements of their customers' equipment without always having the benefit of any standard of cleanliness to work to. Understandably they also have their own opinions on the best solutions to the problem.

CLEANLINESS STANDARDS AND CONTROL

A great weakness in fuel handling procedure has been the lack of a specific cleanliness standard and a practical method of sampling and assessing solid contamination present in fuel.

Although I have no direct knowledge of it, there is probably much being done by the oil companies in the development of sampling and assessing techniques and it is gratifying to know that Trans-Canada Air Lines have a working procedure capable of accurately measuring the weight and size of solid contamination down to less than 1 mg of solid per Imperial gallon and 0-5 microns in diameter; this has been of great assistance in cleanliness control.

†Received 14th March, 1958.

*Sales and Service.

As for the establishment of cleanliness standards, this is the responsibility of the designers and manufacturers of the equipment using the fuel and existing specifications should be rewritten to include specific requirements.

FUEL HANDLING

In the course of widely scattered visits to airlines, aircraft manufacturers and operators, engine manufacturers, oil companies and filter companies, it was readily apparent that very few people at the operating level, i.e. maintenance technicians, fuel dispensers, mechanics etc., had much idea of the extremely high standards of cleanliness demanded. In most cases, while provision was made for recording pressure drop, filter changes etc., and certain broad tolerances were laid down, the matter was treated as of so little importance that very rarely could specific answers be given to such questions as:

(1) How often are elements changed?
(2) What do you expect to see in the "sight glass"?
(3) What is the normal pressure drop across your filter unit?
(4) What is the maximum pressure drop across your filter unit?
(5) How often do you calibrate your pressure gauges?
(6) What type and what is the normal micron value of your filter element?
(7) How often do you clean out the filter unit and how?
(8) What do you inspect the filter unit for?
(9) When do you inspect fuel hose nozzle screens?

It was striking to note the almost childlike faith in the fact that "anyway there was a good filter further down the line and though some contamination got in because the cap was left off or a hose nozzle dropped in the mud etc., well that was why the engine had a good filter . . ." This vague reliance on the "other" fuel filter appears more widespread than is generally realized and is inducive to careless handling with its attendant dangers.

It cannot be emphasized too strongly that the place to start the cleaning process is the refinery and *each step* towards the aircraft should be carefully controlled, using the best available equipment and strictly imposing rigid minimum handling requirements. This does not imply that engine filters are not needed but it does go a long way towards ensuring that the last and smallest filter in the line is not expected to remove large quantities of contamination at a point where the cost of filtration is much higher and where a filtration failure can have dire

results. That the airlines and the oil companies are now well aware of the need for very clean fuel is evidenced by the papers referred to earlier and by the program instituted recently by Imperial Oil to implement the recommendations of Reference 3.

All this takes time, however, and meanwhile existing storage and trucking facilities have to be used. The question that should be uppermost in our minds is how to use them to the greatest advantage and I give some recommendations later in this paper.

LUBRICATING PROPERTIES

Apart from questions of fuel cleanliness, it has been frequently claimed that Kerosene is liable to give less trouble than JP4. Without becoming involved in deep technicalities, it certainly appears reasonable to assume that, from the point of view of lubrication, the fuel with the higher sg should be better.

Some interesting evidence emerges from a study of the fuel pump life experienced by four operators. Firstly, Operator A was obtaining a life of 1,000 hrs (improved from 650) with numerous failures, using JP4; Operator B, using the same aircraft as Operator A, was obtaining 3,400 hrs with no failures, using Kerosene. At first sight, the increased life experienced by Operator B appeared to be attributable to the type of fuel but the picture was confused by considering Operator C who also used Kerosene but got only 1,000 hrs life with the same fuel pump. Operator D using basically the same fuel pump but under conditions of maximum load most of the time and running at higher speed got a normal life of 300 hrs, using JP4.

In an attempt to find an answer to this problem, an examination of the handling procedures claimed by the various operators produced the following information:

Operator A *– 650 hrs fuel pump life*:
(1) Fuel: JP4
(2) 90% fuel from one oil company
(3) Bottom suction employed generally
(4) Vertical tankage of relatively low capacity (15,000 gals average)
(5) Dispensing to same general standard employed for AVGAS

Clean-up program resulting in 1,000 hrs fuel pump life:
(1) Adequate settling time in tanks before use
(2) Latest filtration elements rated at 2 microns situated downstream and in series with combination filter/water stripper rated at 5 microns
(3) New hoses flushed with 10,000 gals of fuel (based on actual tests)
(4) Importance of clean fuel continually emphasized to handling crews
(5) Periodic sampling and laboratory tests

Operator B *– 3,400 hrs fuel pump life*:
(1) Fuel: Kerosene
(2) All fuel from one oil company
(3) Floating suction employed
(4) Settling time allowed
(5) Horizontal tankage
(6) Latest filtration equipment

Operator C *– 1,000 hrs fuel pump life*:
(1) Fuel: Kerosene
(2) Fuel from one main and various lesser suppliers
(3) No control of storage and dispensing conditions

Operator D *– 300 hrs fuel pump life*:
(1) Fuel: JP4
(2) Fuel from various suppliers
(3) Bottom suction employed
(4) Vertical tankage
(5) Settling time doubtful
(6) Mixed filtration equipment
(7) Dispensing to same general standard employed for AVGAS

Based on the foregoing operators' stated handling procedures and on the fuel used in each case, one might conclude that since apparently Operator B is handling his fuel (Kerosene) ideally, it is very clean indeed and he is able to obtain a long fuel pump life. Operator A has demonstrated that by improving his handling in line with Operator B, though using JP4, he shows a substantial improvement and hopes eventually to equal the pump life obtained by Operator B; if and when he does, it would suggest that the relative lubricity of the fuels is, as has been said, "a red herring, hiding the true villain, abrasive contamination in the fuel"[2].

However, I cannot concede that there is indeed no case for lubricity, since the stated procedure of Operator B did not bear close scrutiny in actual practice. The handling of Kerosene by Operator B was in fact much inferior to the handling of JP4 by Operator A – for example, in the following respects:

(1) No settling time was possible at several locations, since fuel was being used as fast as it was being stored.
(2) Floating suction was unserviceable in some cases and might even have been on the bottom.
(3) Only nominal flushing of new hoses was practised.
(4) No records were maintained of filter element changes etc.
(5) Rather indifferent control was exercised over independent haulage contractors.

It is strongly suspected that if samples of the Kerosene used by Operator B had been taken at the refuelling nozzle, they would have been found to contain much more contamination than the JP4 used by Operator A. Yet Operator B has never experienced a fuel pump failure in over 1,500,000 hrs operation and many pumps are returned to service without any part replacement! The only conclusion I can draw from the foregoing is that fuel pumps will tolerate more contamination in Kerosene than in JP4 and will still give better service.

The above conclusion is supported, in my mind, by considering the rejection rate of Flow Control Units. The FCU has not the same problem as the fuel pump: the latter is susceptible to rapid deterioration in the presence of abrasive contaminants; but the FCU is susceptible to plugging of very fine control orifices, valves etc. If contamination is present in sufficient size and quantity, then, regardless of the fuel used, malfunctioning of the FCU will probably occur – whether or not lubricity is a factor in the life of the fuel pump. Malfunction of

the FCU is usually not nearly so spectacular as pump failure and consequently has been partly obscured in the past for this reason.

It is interesting to note that the ratio of FCU to fuel pump failures is usually very high and Operator B, using Kerosene and getting such excellent results with fuel pumps, is apparently worse off as far as FCU's are concerned. Now if the Kerosene in question was relatively clean by virtue of a supposedly ideal handling procedure, then surely the same good results experienced with fuel pumps should have been repeated with FCU's which are much more sensitive to fuel contamination.

The consequences of FCU failure and failure or reduced life of fuel pumps are serious. They affect safety, reliability, economy and, in the military case, loss of defence efficiency. The importance of cleanliness of fuel, therefore, cannot be overemphasized.

WATER CONTAMINATION

It will be noted that there has been no reference so far to water contamination of fuel. This does not imply that it is not a serious problem where it exists. Fortunately water contamination is not common and, when it does occur, the existing water strippers (if serviceable) do a good job. If the water strippers are unserviceable and free or entrained water is present, it can be readily detected by observing the sight glass. In addition water drain taps are provided in most filtration equipment and, from observation, they appear to be checked daily at most places. The presence of rust is invariably a clear indication of water contamination and shows that the filtration equipment is not operating properly or that the handling personnel are not fully discharging their responsibilities.

It is recommended that fuel should be constantly sampled during aircraft refuelling for free or entrained water. At least one oil company and one filter company are understood to be developing devices which will automatically monitor the fuel for water contamination during refuelling operations.

One method of checking for the presence of water is to place a small quantity of food colouring in a dry transparent container and to introduce a sample of fuel drained off from the water drain tap. Any free water present will dissolve the food colouring and readily reveal itself. Entrained water, of course, will impart a cloudy appearance to the fuel; the fuel should always be clear.

Dissolved water is not considered a problem within the scope of this paper inasmuch as it has never been associated with component failures.

RECOMMENDATIONS FOR EXISTING FACILITIES

We have certain fuel and certain storage facilities and dispensing systems which cannot be changed overnight. The immediate problem is how to achieve the best results with the available tools at hand.

Fuel

Major factors in the selection of fuel are safety, dependability and economy.

Safety

JP4 is no more dangerous than gasoline and it is believed that no air accident has yet been attributed to vapour explosion.

Dependability

For reasons stated earlier in this paper, I believe that fuel pumps are likely to be more dependable using Kerosene than using JP4. JP4, as it exists at the present time, will continue to be a limiting factor in the life of fuel pumps on current turbine engines in Canadian aircraft.

Economy

Basic price today is not the only factor to be considered in making a choice of fuel. In view of the increasing use of turbine powered aircraft and the extension of use of other Kerosene burning equipment, such as diesel locomotives, the availability of fuel for aviation use, particularly in time of war, must be given due weight.

It is believed that relatively few "crudes" are capable of producing satisfactory straight-run Kerosene ("straight run" fuels do not call for elaborate and costly processing). It is estimated that at the present time only about 5% of available crude oil can be made into satisfactory aircraft Kerosene, while about 50% can be made into wide cut or JP4 fuel.

From the foregoing, it is obvious that JP4 is the more attractive fuel. In my opinion, work should be instituted by the oil companies to bring the lubricating properties of JP4 into line with those of Kerosene, if this is possible chemically and economically, and with acceptable departures from other requirements of the specification; the alternative is to accept some life limitations on existing fuel pumps.

Storage

Settling Time

It has been emphasized that settling time is of great importance in eliminating contamination and generally with some forethought and organization it should be relatively easy to ensure that it is provided for. Multiple storage tanks are of course a first essential and there are very few places where there is only one storage tank.

Settling rates for a 6 micron particle of hydrated rust in AVGAS and Kerosene are as follows:

AVGAS approx 23 in/hr at 60°F and 0.73 sg
Kerosene approx 5.5 in/hr at 60°F and 0.80 sg

A 1 micron particle would take 27 times longer in AVGAS and 36 times longer in Kerosene, namely 0.85 in/hr and 0.065 in/hr respectively.

The existing recommended settling times for Kerosene are based not on the calculated figures but on the fact that since the "generally accepted (oil) industry standard of settling time for AVGAS is 15 min/ft of depth" then Kerosene, requiring approximately 4 times as long as AVGAS, "should be permitted to settle a minimum of 1 hr/ft of depth"[1]. It is difficult to reconcile these recommendations with the actual settling rates given above and it is hoped that the parties concerned are able to justify the existing standards or will consider making new recommendations, especially for JP4 fuel.

Input Filtration

The foregoing should emphasize the need for micronic filtration on the "in" side of a bulk storage system. Generally speaking, it appears that fuel being supplied to main storage tanks is not filtered micronically.

Suction

The majority of installations employ bottom suction. The possibility of modifying existing facilities from bottom to floating suction should be considered and the following points should be borne in mind.

(1) The best available micronic filters should be employed with piping modified if necessary to permit filtration "in" as well as "out" of storage.

(2) Periodic sampling should be adopted using a method such as that developed by TCA and Imperial Oil which is outlined in the Appendix.

(3) Fully informed personnel should be held responsible for fulfilling all specified requirements. This will mean an educational program and the possibility of creating a "Fuel Technician" grading, requiring definite training and qualifications, should be considered.

(4) Procedures and schedules for changing elements, checking and calibrating gauges and cleaning out filter units should be laid down and rigidly enforced.

(5) Full inspection procedure of fuel units should be laid down and rigidly enforced.

(6) Newly fitted pipe lines or hoses downstream of the filter should be flushed with 10,000 gals of filtered fuel[5].

(7) Refilling stack pipes should have baffles to prevent unnecessary disturbance of sludge at the bottom of the tank.

Dispensing systems

In connection with the dispensing systems certain recommendations can be put forward to complement rather than replace existing regulations. These are as follows:

(1) Trucks used to transport and dispense JP4 should not carry any other fuels.

(2) Tanks and piping should be lined with epoxy resin or equivalent[3]. (Insulation in this fashion may introduce a serious hazard with existing fuels and the effect on the rate of discharge of electrostatic may require investigation.)

(3) The best available filtration equipment should be employed.

(4) Upon defuelling, the fuel should be filtered back to storage or truck tank via truck filters.

(5) Sampling equipment should be installed at fuel nozzles.

(6) Adequate vent filtration should be provided.

(7) "Tight fill" connections should be employed if available; otherwise great care should be taken to ensure that contamination is not introduced through manhole covers during truck refuelling. ("Bottom fill" is also a safety recommendation as a means of reducing generation of dangerous static.)

(8) Procedures and schedules for changing elements, checking and calibrating gauges, cleaning out filter units and thorough inspection (against a check sheet) should be laid down and rigidly enforced. Existing procedures and schedules should be reviewed to ensure their accuracy.

(9) New refuelling hoses should be flushed with about 10,000 gals of fuel.

(10) Nozzle screens should be checked and cleaned daily.

(11) Hose nozzles should never be laid on the ground and should be suitably capped when not in use.

RECOMMENDATIONS FOR THE FUTURE

Having ensured that present equipment is being used to the best advantage in the light of experience, we should consider what further steps can be taken and perhaps specify features which should be incorporated in future fuel handling installations and techniques. The following recommendations are put forward:

Main Storage

(1) Stainless steel or lined storage tanks

(2) Horizontal tanks

(3) Floating suction

(4) Micronic filtration "in" and "out"

(5) Revised settling times

(6) Rigid inspection procedures

(7) Rigid maintenance of records

(8) Constant sampling

Fuel Truck

(1) Stainless steel or lined tanks

(2) Pressure re-filling or "Tight fill" fuelling orifice

(3) Filter on vent

(4) Water stripper/filter combination and "polishing" filter in series

(5) All fuel pumped by truck, whether fuelling or defuelling, should pass through micronic filters as in (4) above

(6) Fine nozzle screens, such as stainless steel 1400 mesh, should be considered

(7) Non-metallic nozzle spouts might be considered

(8) Constant sampling of fuel at nozzle

(9) Nozzles capped when not in use

CONCLUSION

It is hoped that this paper will be helpful and its recommendations accepted in the spirit in which they have been given. The opinions expressed are based on my own observations and enquiries and I believe that only improvement can result from informal investigations of this nature.

I must thank all those who cooperated in supplying information, both oral and written, and particularly the Engineering Department of Trans-Canada Air Lines.

APPENDIX

To determine fuel contamination:

M.M. = Millipore Membrane

(1) Weigh M.M.
(2) Place M.M. in drying oven at 210°F for 30 minutes
(3) Place M.M. in dessicator for 60 minutes, then weigh and record
(4) Install M.M. in special plastic container
(5) Install plastic container in "bomb"
(6) Draw sample of fuel from nozzle of refuelling hose or where else desired
(7) Remove plastic container and cap orifices
(8) Flush plastic container using pre-filtered petroleum ether

N.B. Particle free solvent referred to is obtained by filtering through M.M. four times and observing the Tyndall effect.

(9) Repeat 2 above
(10) Repeat 3 above
(11) Calculate contaminant by weight per Imp. Gal. using the formula:

$$\frac{[\text{Final weight (10 above)} - \text{Initial weight (3 above)}] \times 4546}{\text{Volume filtered in millilitres}}$$

(12) Mount M.M. on clean glass slide over immersion oil (ex Fisher-Corytille's Type B) and secure cover glass using Permount 12-568.
(13) Perform a particle count – counting a minimum of 50 fields and recording the number of particles in the following micron ranges:

5-10 10-20 20-30 30-50 50-100

(14) Observe and record largest particle and any other pertinent observations such as water, fibre etc.

Additional Analysis

By "ashing" the M.M. the weight of inorganic sediment may be obtained.

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(3) Willets, R., and Love, D. D. – *Jet Fuel Handling*, Imperial Oil Co.
(4) Robinson, L. L. – *Fuel System Contamination and Filtration*, Allison Division GMC, Presented to A.F.A.I. Conference on Turbo Jet Propulsion Systems, Palm Springs, Calif., January 1958.
(5) Imperial Oil Service Bulletin, No. 2-58, 17 January, 1958.

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C.A.I. LOG

SECRETARY'S LETTER

IT WOULD seem to be the Secretary's job to visit all the Branches at least once in the course of a year. In 1957-58, I am sorry to say, I failed. My apologies are due to Montreal and Cold Lake. Although I never attended a Branch meeting in Montreal, I did spend two days with them on the occasion of the IAS/CAI Meeting last fall; but I never got to Cold Lake at all, for which I must blame the weather which prevented my leaving Edmonton when I was there in January. I shall try to do better in the next twelve months.

TORONTO

My visit to the Toronto Branch was put off to the eleventh hour but I did succeed in attending their Annual General Meeting at the end of April. As is always the case when I visit Toronto, I found that the geography had changed completely and my many friends had not changed at all.

The Toronto Branch ended the fiscal year with 701 members; in addition 26 were lost during the year for a variety of reasons. There is something to be said for the contention that the Branch, as a Branch, is too big but, in any event, it is interesting to remember that, when the CAI was formed four years ago, we thought that the total membership of the whole Institute might, with reasonable luck, exceed 650 some day!

STUDENT SECTIONS

Another brief excursion by Headquarters staff was made by Mr. Taylor to Kingston on the 30th April. He attended a meeting of the Ottawa Branch Student Section at the RMC. I hope that in the coming year the Ottawa Branch will be able to develop the very promising relationship that has been established with their rather remote Student Section during the last season.

The organization of a satisfactory Student Section in Montreal has always presented difficulties, chiefly, I think, because there are so many academic institutions in that city that our Student members seem to be segregated into as many watertight compartments. I know that this problem has been receiving some attention from the Montreal Branch during the past year and there is reason to believe that a solution is now not far away.

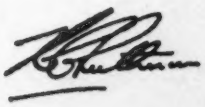
In the meantime, the Student Sections of the Toronto and Vancouver Branches, good as they are, ought to attract more students. The Toronto Branch, I suggest, might make some inroads into the Ryerson Institute of Technology; and Vancouver might try to interest the University of British Columbia.

Student affairs are pretty quiet just now but the Branches might do a little planning, to be ready for the beginning of the academic year.

FIRST INTERNATIONAL CONGRESS

Since the Journal is not issued in July and August, this is my last opportunity to draw attention to the First Congress of the ICAS, which will be held in Madrid early in September. A notice about it appeared on page 132 of the April issue.

We have the necessary application forms here and I hope that I shall soon have fairly full information about the programme and other arrangements. It will be an important meeting and anyone going over to Europe in the latter part of the summer owes it to himself professionally to try to attend.



THE NEXT TWELVE MONTHS

(1) FIRST CONGRESS IN THE AERONAUTICAL SCIENCES

8th to 13th September, 1958

Madrid, Spain

Forms of application to attend this International Congress and particulars of the programme may be obtained from the Secretary of the CAI.

(2) ANNUAL JOINT IAS/CAI MEETING

7th and 8th October, 1958

Chateau Laurier, Ottawa

For an outline of the programme see page 199; details will be sent to all members in August.

(3) SPECIAL ANNIVERSARY MEETING

23rd and 24th February, 1959

The Queen Elizabeth, Montreal

On the 23rd February, 1909, Mr. J. A. D. McCurdy of Dr. Alexander Graham Bell's Aerial Experiment Association made the first flight by a British Subject in the British Empire, at Baddeck, Nova Scotia. The theme of this meeting will be "The Next Fifty Years"; the CAI will look towards the technical possibilities of the Centenary of Mr. McCurdy's flight.

(4) ANNUAL GENERAL MEETING 1959

15th, 16th and 17th June, 1959

Keltic Lodge, Ingonish, Nova Scotia

This will be no ordinary Annual General Meeting; 1959 will be no ordinary year. The Meeting will include a visit to Baddeck in celebration of the 50th Anniversary of powered flight in Canada.

APPOINTMENT NOTICES

The facilities of the Journal are offered free of charge to individual members of the Institute seeking new positions and to Sustaining Member companies wishing to give notice of positions vacant. Notices will be published for two consecutive months and will thereafter be discontinued, unless their reinstatement is specifically requested. A Box No., to which enquiries may be addressed (c/o The Secretary), will be assigned to each notice submitted by an individual.

The Institute reserves the right to decline any notice considered unsuitable for this service or temporarily to withhold publication if circumstances so demand.

Positions Vacant

Senior Technical Illustrators: Vacancies exist for experienced men with a minimum of five years experience of aircraft illustration work. Five day, forty hour week. Usual fringe benefits after qualifying period. Send details of qualifications, education, experience etc. to Industrial Relations Manager, Northwest Industries Limited, Box 517, Edmonton, Alta.

Technical Assistant: A vacancy exists for a Technical Assistant with a background of experience related to the overhaul of gas turbine fuel systems and accessories. Education to Engineering Standard or equivalent (Higher National Certificate). Applications should be made in writing only, giving complete outline of education, experience and salary required to Assistant Personnel Manager, Rolls-Royce of Canada, Ltd., Box 1400, Station O, Montreal 9, Que.

BRANCHES

Vancouver

Reported by R. W. Van Horne

April Meeting

The Annual General Meeting of the Vancouver Branch was held in the Thunderbird Room on the 19th April and was attended by 125 members and guests.

Mr. H. H. Ollis, Chairman, opened the business meeting and recapped briefly the activities of the Branch during the past season.

Copies of the Executive Committee annual report having been circulated, members were asked for comments. It was moved and seconded that the report be as recorded.

Since there had been no further nominations for the proposed slate of officers for the season 1958-59, Mr. Ollis then introduced the new Executive. After wishing the new Executive well in the coming season, the rostrum was turned over to the new Chairman, Mr. R. J. McWilliams. Mr. McWilliams closed the business meeting by expressing the hope that our 1958-59 season would be one of further progress in the Vancouver Branch.

Dining and dancing followed until midnight.

Toronto

Reported by H. V. Braceland

March Meeting

The last regular meeting of the Toronto Branch was held on the 11th March with Mr. J. W. Ames as Chairman. Attending the meeting were 71 members and 81 guests. The speaker for the evening, Mr. J. O'Malley of Bell Aircraft, was introduced by Dr. G. W. Johnston and, following his talk, was thanked by Dr. D. H. Henshaw.

Mr. O'Malley, who has had considerable experience with VTOL aircraft at Bell, outlined some of the basic parameters and discussed to some extent Bell's initial studies which took place in order to determine the best approach to VTOL aircraft. In his paper, the speaker discussed the basic principles, such as thrust-weight ratios and angle of incidence related to flight path, and other important factors including the reasons for the decisions in selecting rotatable engine pods and wing configurations.

As a result of the above discussion, Mr. O'Malley showed quite clearly why Bell built their first prototype VTOL aircraft with a rotatable thrust centre line from existing hardware, such as a Cessna wing and a Bell helicopter undercarriage etc.

A discussion of the first prototype airplanes together with slides and films made this talk one of the most interesting in the Toronto Branch this year.

During the latter part of Mr. O'Malley's discussion, he outlined the possibilities and potential of VTOL aircraft, not only in military aviation but in commercial applications. He considered that the same principles which applied to the existing Bell VTOL aircraft should be applied to commercial aircraft since this approach is of great economic value not only for the airlines but for those responsible for airport facilities and, in particular, runways. The speaker stressed the importance in commercial operations of the reduction in time in getting the passengers from the heart of a city to the airport which, in effect, would considerably reduce block to block speeds.

Winnipeg

Reported by D. A. Newey

March Meeting

Thirty-two members and eight guests attended the March meeting of the Winnipeg Branch which was held in the Westinghouse Auditorium on Tuesday, 25th March. This meeting took the form of a Symposium on missiles. Mr. C. M. Hovey, Branch Chairman, acted as chairman of the symposium, in which Mr. H. G. Sevier and Mr. C. F. Fuller of Bristol and Professor F. G. Maccabee of the University of Manitoba took part.

Mr. Sevier opened the discussion with an outline of the progress which had been made in the missile field, illustrating his discussion with projections of photographs tracing the evolution of the missile from the comparatively short range support types to the intercontinental ballistic missile. Mr. Sevier enlarged on the problems associated with various types of missiles and the differences in geometry which had developed between the British and American technical programmes.

Prof. Maccabee followed, dealing with, primarily, propulsion aspects of missiles. He first reviewed the possible field of propulsion units which would be used in missiles during the immediate future. He dealt with the limitations of air breathing engines, particularly with regard to the effect of reduced pressure at altitude on engine performance, and also the over-riding limitation of kinetic heating.

This had led to the choice of rocket propulsion, especially with the use of solid rockets, for all except those roles explicitly requiring air breathing engines, such as low altitude long range missiles like the Snark.

Prof. Maccabee illustrated his talk with further projections of missile photographs and also a very comprehensive coverage of charts which he had prepared, illustrating the effects of the various factors imposed on the rocket during flight at the extremes of altitude encountered in such operations.

The third member of the panel, Mr. C. F. Fuller, then gave an outline of the progress made in connection with guidance systems. Mr. Fuller covered the field of electronic guidance of missiles, explaining that unfortunately much of the progress which had been made in this connection was of such a nature that only those intimately working with it could give a comprehensive review of the details and such people were invariably restricted by security considerations from discussing such details. However, even with the limitations thus imposed, Mr. Fuller gave the meeting a considerable coverage of the problems arising and the approaches to solutions in the field of weapons guidance.

The meeting then saw a film which had been produced by the British War Office on the German V2 Rocket. This film, which covered one of the early developments in ballistic missiles, still had a surprisingly modern look in terms of the principles which were being applied to modern missile operation.

Mr. J. G. Davidson thanked the speakers at the close of the meeting.

May Meeting

This was the Annual General Meeting of the Branch and took the form of a dinner, following which Reports were presented by the Executive Committee and the Committee Chairmen.

The highlights of the Reports indicated continued slight growth in membership whereby losses due to transfers

etc. were more than made up by new membership affiliations. Some concern was expressed that a substantial percentage of membership were not attending monthly meetings and it was suggested that further action would be necessary in this regard.

The finances of the Branch were satisfactory as far as CAI funds were concerned although there was some problem of losses on the social activities, which would require a concerted effort in the future.

Following the report from Mr. C. M. Hovey, the retiring Chairman, the new Executive were introduced to the membership.

At the close of the dinner the meeting was addressed by Mr. Ross Screaton, President of the Winnipeg Flying Club, who is also President of the 50th Anniversary Co-ordinating Committee of Winnipeg. Mr. Screaton outlined the objects of the Committee and asked for support of the CAI membership.

Following this those assembled saw two films, the first flight of the Avro Arrow and the initial film on High Speed Flight.

There were 53 members and 25 guests attending the meeting.

Halifax-Dartmouth Branch Executive Committee 1958-59: (l to r) CPO R. L. S. Sabourin (Chairman), Mr. R. Wallworth (Vice-Chairman), Lt. J. A. Turner (Secretary), Mr. E. C. Garrard (Councillor), CDR E. B. Morris (Councillor) and Lt. N. B. Davis (Treasurer)

Halifax-Dartmouth

Reported by Lt. J. A. Turner

April Meeting

The second Annual Meeting of the Halifax-Dartmouth Branch was held in the cinema of the CPO's Mess, HMCS Shearwater, on the evening of the 16th April. A total of thirty-eight members and guests were present.

The Chairman, Mr. E. C. Garrard, presented the Annual Report which showed that the Branch was in a relatively sound financial position.

The Branch was honoured to have Mr. H. C. Luttman, Secretary of the Institute, present for the meeting. After being introduced to the members, Mr. Luttman briefly reviewed the progress of the Branch noting particularly the substantial increase in membership.

The Chairman then gave a brief resumé of the Branch activities over the past year. The Chairman also expressed his thanks, on behalf of the Branch, to the CPO's Mess for making their Mess available for the meetings throughout the current season.

The business portion of the meeting was concluded by the report of the election of Officers for the 1958-59 season.

After a short intermission, a film entitled "High Speed Flight: Approaching the Speed of Sound" was shown. The meeting closed with a short address from the incoming Chairman, CPO R. L. S. Sabourin.

Edmonton

Reported by C. W. Arnold

April Meeting

The Edmonton Branch held its April meeting at the RCAF Association (700 Wing) Mess on April 16th, 1958, at 8.00 pm. Fifty-five members and guests attended.

Mr. J. Bristow, Chairman, presided.

In lieu of a guest speaker, two films were shown:

"High Speed Flight", the first of a series of films on the same subject which started with an analysis of sound waves in air and the relation of the speed of sound to the behaviour of high speed aircraft.

"Song of the Clouds" told that no frontiers are marked on the spacious highways of the air. It dealt with co-operation on international air routes which concern IATA, The International Air Transport Association, and ICAO, The International Civil Aviation Organization.

The meeting was then adjourned.

Calgary

Reported by H. E. Hampshire

May Meeting

The Calgary Branch met at the Institute of Technology and Art on Thursday, 15th May, 1958, primarily to elect a slate of officers for the season 1958-59. Twenty-one members and guests were in attendance. This rather small attendance was aggravated by the absence of our Student members, who were elsewhere in the building undergoing examinations!

Elected officers for the 1958-59 season were announced.

The newly elected Chairman, Mr. W. A. B. Saunders, outlined the proposed Branch activities for the coming season and stressed the importance of full co-operation from all members to ensure that this new Branch gets off to a good start in the fall.

The meeting concluded with the showing of two excellent interest films, namely, "High Speed Flight" and "The Super Constellation".

MEMBERS

NEWS

F. M. Hanna, A.F.C.A.I., has joined George Kelk Ltd. as Assistant Manager. He was formerly Technical Assistant to the President, Photographic Survey Corporation.

R. B. McIntyre, A.F.C.A.I., has resigned his position as Assistant General Manager of Dowty Equipment of Canada Ltd., to take up an appointment as Assistant Engineering Director of De Havilland Aircraft of Canada Ltd.

J. E. Fox, M.C.A.I., has been transferred from Lockheed's Georgia Division to the Missile Systems Division at Sunnyvale, Calif., where he is working as a Design Engineer.

A. J. Geraghty, M.C.A.I., has retired from the RCN and is now acting in the capacity of U.K. representative for Rolls-Royce of Canada Ltd.

W. H. Riggs, M.C.A.I., who recently became Works Manager of Avro Aircraft Ltd., has now been appointed Vice-President, Manufacturing.

A. K. Woodill, M.C.A.I., has resigned from Orenda Engines Ltd. on his appointment as Production Officer with the Department of Defence Production.

D. C. Quin, Associate, formerly Senior Production Officer, Department of Defence Production at Scottish Aviation Ltd., Scotland, has been transferred to Ottawa as Section Head of Airframe and Overhaul.

J. D. Koppernaes, Technical Member, recently resigned his position with the Aluminum Co. of Canada to return to Norway to take up the post of Manager, H. Koppernaes & Sinner, Aalesund.

R. J. Gardener, Junior Member, has moved from Vancouver to England where he now works as a Design Draftsman with Sir W. G. Armstrong Whitworth Aircraft Ltd.

DEATHS

It is with deep regret that we record the deaths of **F. M. Haines, M.C.A.I.** and **G. W. MacDonald, Associate.**

Mr. Haines, who died on the 27th April, was Production Director of Canadian Applied Research Ltd.

Mr. MacDonald died on the 10th May. At the time of his death he was General Secretary, Canadian Patents and Development Ltd. and General Counsel, National Research Council, Ottawa.

ADMISSIONS

At a meeting of the Admissions Committee, held on the 11th May, 1958, the following were admitted to the grades shown.

Member

M. F. R. Burton, Design Engineer, Lucas-Rotax Ltd., Scarborough, Ont.: *19 Four Oaks Gate, Toronto 6, Ont.*

S/L A. J. Campbell, RCAF, Logistics Coordination, AMC HQ, Ottawa, Ont.: *894 Eastbourne Ave., Ottawa, Ont.*

H. St. L. Dannatt, Engineer A, Canadair Ltd., Montreal, P.Q.: *1580 Ouimet St., Apt. 28, Ville St. Laurent, Montreal, P.Q.*

A. Frenkel, Senior Designer, Bristol Aircraft (Western) Ltd., Winnipeg, Man.: *Ste 10A Tudor Apts., 281 River Ave., Winnipeg, Man.*

G. J. Grint, Group Leader, Mechanical Design, Canadian Aviation Electronics Ltd., Montreal, P.Q.: *1276 Montpellier, St. Laurent, Montreal, P.Q.*

Y. A. Helleboid, Sales Manager, Aviquipo of Canada Ltd., Montreal, P.Q.: *5948 Beurling Ave., Verdun, P.Q.*

F. G. Jeffery (on transfer from Technical Member)

P. S. Keedwell, Chief Draftsman, Can Aero Consultants Ltd., Toronto, Ont.: *11 Nugent Rd., Toronto 15, Ont.*

J. A. Kemp (on transfer from Technical Member)

J. Leyds, Preliminary Design Engineer, Avro Aircraft Ltd., Malton, Ont.: *47 Parent Ave., Downsview, Ont.*

J. A. MacDonald, Sales Engineer, Vapor Heating (Canada) Ltd., 3955 Courtrai Ave., Montreal, P.Q.

E. V. Mackenzie, Defence Production Officer, Dept. of Defence Production, Ottawa, Ont.: *Rural Route, Cantley, P.Q.*

J. D. F. MacNaughton (on transfer from Technical Member)

G. L. Oates, Stress Engineer, Avro Aircraft Ltd., Malton, Ont.: *2 Hill Heights Rd., Apt. 39, Toronto 14, Ont.*

Surgeon LCDR (P) H. D. Oliver, RCN, Principal Medical Officer, HMCS Shearwater, N.S.: *1 Firefly Terrace, Shearwater, N.S.*

W. R. J. Palmer, Section Head, Repair and Overhaul Group, Service Dept., Canadair Ltd., Montreal, P.Q.: *1715 Edouard Laurin Blvd., Apt. 4, St. Laurent, P.Q.*

S/L H. W. D. Prince, RCAF, Section Head, Aircraft Electrical Accessories, AMC HQ, Ottawa, Ont.: *45 Rigel Rd., Ottawa 2, Ont.*

P. F. Strong, Office Supervisor, Commercial Aircraft Dept., Northwest Industries Ltd., Edmonton, Alta.: *10933 77 Ave., Edmonton, Alta.*

T. A. Walsh, Superintendent of Maintenance, B.C. Air Lines, Ltd., Vancouver, B.C.: *5980 Columbia St., Vancouver, B.C.*

H. D. Walton, Combustion Engineer, Orenda Engines Ltd., Malton, Ont.: *30 Raven Rd., Toronto 15, Ont.*

M. B. P. Watson, Engineer, Special Projects Group, Dept. 7002, Avro Aircraft Ltd., Box 4004, Terminal A, Toronto, Ont.

T. J. Unger (on transfer from Technical Member)

Technical Member

W. R. Benjamin, Toolmaker, Enamel and Heating Products Ltd., Aircraft Division, Amherst, N.S.: *17 Chamberlain St., Amherst, N.S.*

LCDR (P) J. R. Burns, RCN, Staff Officer Air to Flag Officer Naval Division, HMCS Patriot, Catherine St. N., Hamilton, Ont.

F/O R. J. Cockburn, RCAF, Test Pilot, AAED/CEPE, Cold Lake, Alta.: *c/o Officers' Mess, RCAF Stn. Cold Lake, Alta.*

G. N. Gale, Design Draftsman, Avro Aircraft Ltd., Malton, Ont.: *12 Datchet Rd., Downsview, Ont.*

F/O R. J. Hicks, RCAF (on transfer from Student)

Lt. C. S. B. Langford, RN, Engineering Officer of VT-40 Squadron, HMCS Shearwater, N.S.

J. W. F. Millman, Defence Scientific Service Officer, Naval Research Establishment, Dartmouth, N.S.: *421 Windsor St., Apt. 26, Halifax, N.S.*

J. Murray, Electronics Supervisor, Spartan Air Services, Box 551, Ottawa, Ont.

J. B. Phillips, Instructor, Provincial Institute of Technology and Art, Calgary, Alta.: *331A - 34 Ave. N.E., Calgary, Alta.*

Junior Member

F/O H. W. Causier, RCAF, (on transfer from Student)

D. R. Hennig (on transfer from Student)

Student

G. H. Hofmann, Sir George Williams College, Montreal, P.Q.: *715 Grosvenor Ave., Westmount, P.Q.*

F/C K. B. Sinclair, Canadian Services College, Royal Roads, Victoria, B.C.

W. G. Wells, Nova Scotia Technical College, Halifax, N.S.

Associate

F/O W. J. Albrecht, RCAF, (on transfer from Student)

Lt. C. G. Waite, RCN, Aircraft Provisioning Officer, Directorate of Aviation Stores, Ottawa, Ont.: *37 Wychwood Dr., Aylmer, P.Q.*

SUSTAINING MEMBERS

NEWS

Orenda Engines Limited has announced a programme of technical assistance to Bavarian Motor Works (BMW) of Munich, the company designated by the West German Government to repair and overhaul Orenda turbojet engines which power the Canadian-built Sabre aircraft of the German Air Force.

The programme calls for technical assistance "where and when needed". This will include among other things the training of BMW personnel both in Germany and at the Orenda plant at Malton, assistance in setting up procedures and in the purchase of some capital equipment. Orenda will supply the necessary tooling. Spare engine parts will be supplied from Orenda's Malton plant when BMW's repair and overhaul programme gets underway.

An Orenda man is already in Munich as Resident Technical Representative at the BMW plant.

The Company also announced the formation of a subsidiary company to supply diesel power units to Canadian industry. The name of the subsidiary company is Orenda Industrial Limited. It will take over and expand the operations of Brush Aboe (Canada) Limited, Brush Group Sales (Western Canada) Limited, and Brush Aboe Incorporated of New York. Head Office will be in Toronto, with branch offices at Vancouver and Montreal.

Initially Orenda Industrial will market and service products supplied by the Brush Group companies in the U.K., including a full range of the well established diesel lines of Petter, Petter-Fielding, Mirrlees, National, McLaren. Manufacturing in Canada will take place on a long-range basis as it proves necessary.

The Brush Group has over 50 years experience in the diesel and electrical fields and manufactures, among other products, a complete line of diesel engines ranging from 1½ hp to 4,000 hp for industrial and marine uses.

Canadian Applied Research Limited has concluded an agreement with Robot Berning & Co., of Dusseldorf, West Germany, whereby the Canadian company will handle the camera products of this firm for the industrial and scientific field in Canada.

The ceremony of handing over the Argus to Maritime Air Command

Robot Berning & Co. have been manufacturers of fine amateur and industrial cameras for many years and are world renowned for their engineering and workmanship.

It is also learned that the Canadian Applied Research R-Θ Navigation Computer System has been chosen by the Belgian Air Force for installation in its Canadian-built CF-100 jet interceptors.

Under joint Canada-U.S. mutual aid arrangements 53 of the Avro Aircraft CF-100's are being supplied to the Belgian Air Force. Delivery of the aircraft by RCAF aircrew has already begun. It is expected the order will be completed this summer. Canadian Applied Research technical representatives will supervise the installation of the navigation equipment in Belgium.

While the amount of the R-Θ contract has not been disclosed, it is expected to be approximately $1,000,000. This is one of the largest orders for Canadian designed and manufactured electro-mechanical instrumentation equipment ever secured outside Canada in peacetime.

The Toronto company's R-Θ device won the contract in competition with other systems manufactured by electronics and instrumentation firms in North America and Europe. Adoption of the R-Θ by the Belgians now means there will be two similarly equipped air forces in NATO. Canada's CF-100's in Europe are installed with the R-Θ system. Other NATO air forces may soon adopt the R-Θ. It is being evaluated by the French Air Ministry and the Royal Swedish Air Board.

Canadair Limited has provided details of the ceremonies held at Greenwood, N.S., on the 17th May, when the Chief of Air Staff, Air Marshal H. L. Campbell, officially turned over the Argus to Maritime Air Command. A photograph showing Vice-Admiral H. G. DeWolf, Chief of Naval Staff, addressing the gathering appears on this page.

Five Argus aircraft were at Greenwood for the ceremony; in all, ten have flown to date. The Argus will replace the Neptunes now used by No. 405 Squadron at Greenwood and the Neptunes will be transferred to Comox, B.C., where they will replace Lancasters.

Imperial Oil Limited is installing hydrant refuelling facilities for jet fuel at Gander Airport.

The system will be ready in time to supply trans-Atlantic flights by Pan American Airways with the first Boeing 707 to come off the production line. Pan American is racing to be first to operate a commercial trans-Atlantic jet service. Initial flights are expected in July and scheduled passenger service is planned for the fall.

The jet fuel facilities will be incorporated in a new hydrant system for aviation gasoline which Imperial began building at Gander 18 months ago. This $1,000,000 installation will replace a smaller hydrant system which handled only the aviation gasolines used by piston-type engines. An additional $350,000 has been spent at Lewisporte on dockside tankage needed to service Gander.

Fuelling from hydrants recessed below the runway, rather than from tank trucks, is the most efficient way of servicing large jet airliners. For example, it would take four ordinary truckloads to fuel the 124-passenger Boeing 707 for a trans-Atlantic flight.

Imperial Oil's new hydrant system at Gander has 60 of these recessed hydrants. They supply three different fuels to 10 aircraft parking "circles". Other petroleum products are delivered by the airport tank trucks.